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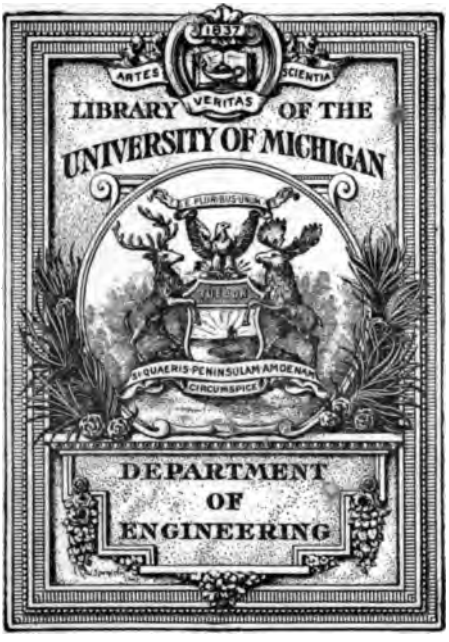
THE MANAGEMENT
— OF —
ENGINEERING WORKSHOPS.

BY
ARTHUR H. BARKER, B.A., B.Sc., &c.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THE MANAGEMENT

OF

SMALL ENGINEERING WORKSHOPS.

BY

ARTHUR H. BARKER, B.A., B.Sc., Wh.Sc.

("R. Y. R.")

Works Manager, Senior Whitworth Scholar, author of "Graphical Calculus," "Graphic Methods of Engine Design," &c., &c.

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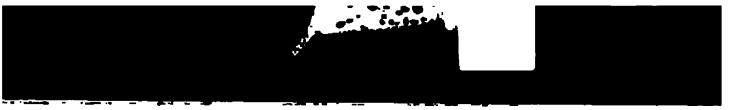

PREFACE.

THE series of articles of which the present volume is a collection have been contributed at various times during the past eighteen months to *The Practical Engineer*, under the *nom de plume* "R. Y. R." The irregular manner of their preparation will account for the discursiveness which it is feared will be discovered in some parts of the subject.

A very varied experience in many capacities in engineering works has convinced the author that there are immense sums of money running to waste in a very large number of workshops, owing to the absence of a definite system of distributing orders clearly and unmistakably, and of properly defining the functions of the various parts of the works.

There are few classes of workshops which are more complicated than those in which engineering work is carried on, and in which there is more necessity for care in clearly defining the duties of each department, and for skill and energy in ensuring that each workman shall have at all times both the material and the instructions necessary to perform his individual part of the work. It is absolutely impossible that any works should be efficiently carried on in the absence of these.

There are only two possible ways of communicating the orders to the works from the office, viz., verbally or in writing. The former involves the continuous presence in the workshop of the official from whom the orders originate, and not only so, but it involves the necessity on his part of knowing and remembering practically everything about every job in the shop. His absence, from any cause, will bring much of the work to a standstill, or will be the signal for expensive mistakes. The possibility of reproducing any order, or referring back to what has been done before, is strictly limited to the accuracy of his memory; in fact, everything depends on him personally. Given a manager perfect in every way, whose continual presence can be relied on without intermission, this system may work well. It may for a time be even economical and convenient—to everybody but the manager himself. The

trouble is that no man has a perfect memory; no man is immortal; no man can be in two places at once. For such a system as this to be satisfactory, the manager must have all these qualifications, and more. He must have been in the works for a very long time, and he must know every tool, pattern, and practically every piece of iron about the place. In practice, of course, this system—or want of system—invariably results in confusion, delay, and loss. The alternative is some carefully-designed and more or less elaborate system of writing all the orders issued, and recording many of the details in connection with the work. If the objects to be attained and the method of working are not very carefully thought out, a large amount of unnecessary labour and a great deal of paper will be wasted, and the whole scheme will probably be abandoned as impracticable. The system here described is not in any sense experimental. Every item of it has been tried in practice, modified as experience dictated, and introduced by the author into more than one works, with results so perfectly satisfactory that he has little hesitation in putting it before other engineers who have the control of workshops.

The main objection entertained by hard-headed business men to the adoption of such systems is that they are apt to increase the expense of management, involving, as many of them do, a considerable increase of staff. Many managers, indeed, go so far as to characterise them as entirely unnecessary "red tape." Red tape, however, is, in moderation, a very useful article of commerce, and is, indeed, absolutely necessary to connect together the various branches of every establishment of considerable size. It becomes objectionable only when there is too much of it. The difficulty in convincing such people of its value is, that by their very objection to written records they are precluded from comparing what is with what might be. No man can be a competent judge of the utility of such a system in a workshop until he has actually compared the results of working with and without one.

Of course, where its adoption would involve a large staff, it may well be held to be thoroughly impracticable in a small works. In this book, however, only such a staff has been assumed as is absolutely indispensable in even the smallest works, and the author knows from experience that such a staff is quite sufficient to perform all the duties here recommended.

He will, however, go further, and assert that almost all the duties and records here specified *must* be, and all the others ought to be,

performed or kept, at some time or another, by somebody connected with the works. Objection has been urged, for instance, by one of his correspondents against the necessity or utility of the pattern list mentioned under the chapter on the drawing office, on the ground that in a small works the foreman pattern-maker should know all the patterns without an index. This very argument emphasises the fact that there must be an index of the patterns somewhere or other in the works. If it is not a definite and permanent one in a book, it is a hazy and perishable one in the foreman pattern-maker's memory. In the one case it is available for every one's use, and in the other case the only person who can use it is the foreman himself, and the use of it, bad as it is, not only costs a shilling an hour in wages, but, in addition, takes the foreman pattern-maker away from his proper duties, viz., the supervision of the pattern-makers.

Emphasis has been laid on the necessity of a generous and judicious outlay on plant, to the neglect of which so many of our older firms owe their decline. A master engineer should design his expenditure in much the same observing and calculating way that a draughtsman designs a machine. It is not enterprise to spend money, and it is not economy to refuse to spend it. It is both the one and the other to consider the ratio between the cost of any proposed change and the saving to be effected by its means. An outlay of £10, which effects a saving of 1s. per week in wages, is money invested at 25 per cent.

Good works management consists of two elements—(1) Promptly supplying to the shop both the material to work on and precise and unmistakable instructions as to what is to be done with it; and (2) seeing that the work ordered is properly and quickly done.

Broadly speaking, the first is the province of the manager himself; the second, that of the foremen. It is a sign of bad management somewhere when these are not efficiently done, and where the people in the works have to do any of the first, or the manager any of the second.

A. H. B.

May, 1899.

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THE MANAGEMENT

OF

SMALL ENGINEERING WORKSHOPS.

CHAPTER I.

Introduction.

In these articles we shall consider the management of small shops, employing anything up to 150 or 200 hands, confining our attention to the internal working of the shop. The commercial management has recently been ably treated by several well qualified and highly experienced writers, who have, however, rather neglected the small items, the careful supervision of which exercises such a marked influence on the balance sheet. To these we shall mainly devote attention.

There are large numbers of old-established small firms in this country which, though working with plenty of capital, and turning out work which cannot be surpassed in quality, yet are steadily losing ground financially. This is attributed by the principals themselves to a variety of causes—labour troubles, the competition of larger and better-equipped establishments, foreign competition, and the like. Though there is, of course, no doubt that these causes operate prejudicially, and will in any case cause the balance sheet to be a very different document to that of former years, when Britain had almost the whole of the engineering trade of the world in her hands, and every shop worth the name was working night and day, yet they are not enough in

themselves to account for the microscopic dividends which with many firms have become the order of the day. Careful observation of small causes of leakage, systematically carried out, will in many cases bring to light an enormous waste of money, which may have been unsuspected for years. This observation, combined with discretion in caulking the leaks, will do much to put things on a more satisfactory footing. Proprietors, or their managers, are in general too little in touch with the actual manufacturing operations. While naturally anxious to keep down expenses to the lowest possible point, they are apt to overdo economy through not being in a position to see so clearly the losses caused by niggardliness (which is only the superlative to economy) in small trifles, as they would do if they performed the duties of foreman. In their anxiety to avoid spending money they will often waste three times the amount they are endeavouring to save. They do not see it themselves (though their foreman does), and they congratulate themselves on saving money, when they are in reality wasting it. The guiding principle must always be that money must not be spent unless there is going to be a definite and adequate return for it, and must not be stinted when there is. As an instance of this mistaken economy, a proprietor will often buy an expensive modern machine tool, and yet be extremely niggardly in properly supplying it with tools and accessories, thus making the machine practically useless for want of a few extra pounds. Of course, the principal's time and energies must naturally be mainly devoted to the commercial side of the work. He cannot be ubiquitous. He is compelled to leave duties to others which he cannot possibly perform himself, and the whole secret of successful managing consists in developing a system whereby all the wires which communicate, as it were, with all parts of the establishment, are combined into two or three which have their ends in the principal's office. The system must be automatic in its action. By means of this network of organisation the principal, be he manager or proprietor, must be in touch

with every part of the establishment. He must have an index map of the whole thing at his elbow, and be able to examine in detail any part of it that seems to require attention.

It is unnecessary to say that this system cannot be developed all at once. Though it needs the co-operation of almost everybody employed about the works, yet it must all be designed at headquarters. Just as a capable draughtsman puts every single detail of his design on paper, leaving literally nothing to be designed or thought out in the works, so the capable manager will leave no single detail of his system to be designed by his subordinates. Every man's duties must be plain and definite, and the whole must fit together like a mosaic.

Just as a large steam engine can be worked more economically than a small one, so a large establishment is much more likely to be efficient than a small one. While the same causes of loss may be in operation in both cases, yet the actual amount of the loss is not proportional to the magnitude of the establishment. The loss from one cause may even be the same in the two cases, and might be insignificant in a large works, but very material in a small one. But the chief cause of the difference is the greater facility with which specialisation can be carried out in large factories. Not only is it easier to keep special men constantly and uniformly employed on certain classes of work, but there are also greater facilities in a large works for obtaining special tools for any particular job. In a small works, on the other hand, it is difficult or impossible to arrange matters so that every man shall be constantly provided with plenty of definite work of one class. At one time there may be a dearth of one particular class of work, while in a few days the amount of work of that class ready to be done may be simply overwhelming. The result is, that men have to be shifted about from their own job to another to which they are perhaps unaccustomed.

Just as a steam engine does not work economically if it is

run irregularly, so a works cannot reach its highest efficiency unless the work flows on smoothly and regularly. To maintain this regular flow, a capacious reservoir, both of work and capital, is necessary, and the necessary size of reservoir is not by any means proportional to the size of the works, but the proportion diminishes as the size of the works increases.

This question of proportion is at the root of the whole difference between a large works and a small one. Thus, while one necessary special tool may be enough for a works employing 1,000 men, it is equally necessary for one employing only 100 men, but doing the same class of work; or, again, the renewal of an old machine tool might in a large works be an insignificant matter, but the same outlay might be so serious to a small proprietor as to induce him to keep the old tool at work long after it ought to have been put on the scrap heap; or, if repair only were needed, it might be the only tool of that class that he had in the place, so that he could not possibly spare it to be repaired, with the result that the wages for fitting are about double of what they would be with a good tool. The latter outlay is of a class that might easily escape the notice of anybody but the fitter himself, and his foreman. The foreman would in many cases be afraid to tell the proprietor of it for fear of being hauled over the coals himself—and it is astonishing for what things a proprietor does feel justified in hauling his foreman over the coals—and so the loss would go on from year to year, unobserved by the management.

Then there is another cause which tends to prevent the continuity of efficient working in a small works. Such works have, as a rule, been founded in the palmy days of engineering by a vigorous and able man, who has developed the organisation from the beginning by his own personality, and whose force of character has kept the wheels working smoothly and regularly. When he is, in the nature of things, removed, another and very different man is apt to step into his shoes, who, being not only unacquainted with

the geography and history of the establishment, but also in consequence ignorant of the all-important details of the system of organisation set up by his predecessor, allows the organic machinery to fall into disrepair, which necessarily introduces chaos into the establishment. This involves a thorough re-organisation *ab initio*, which needs a keen-sighted, strong, and determined man to carry out effectually. Such men are not too common. Generally speaking, a works is never conducted so well as by the man who founded it. Now, in a large firm, the loss of a single man is not so vital. There is more momentum about a large firm than a small one; changes do not take place so rapidly. When a new head comes on the scene, he is surrounded on all hands by well-established customs, and by officials who know their duties. Each mesh of the network is composed of several strands, and if one or more strands do snap, the whole thing is not necessarily thrown into confusion. The new principal is carried along by the current until he acquires, as it were, its velocity. His duties are more cut and dried, and if he is unfit for them the resulting decay is more gradual.

Assuming, then, that commercial arrangements are satisfactory, the points to be aimed at are to have a conveniently designed shop, well supplied with modern tools; to find, employ, and keep good and reliable workmen well, but not over-supervised, by smart and energetic foremen; to make the men contented with their jobs; as far as possible, to keep each man to work of one class, and to keep the stream of work as constant as possible, avoiding disturbances and convulsions of all sorts. If all these considerations are attended to, a shop cannot fail to be efficient, and a neglect of any one of them will be a very expensive luxury.

CHAPTER II.

The Geography of the Works.

It is difficult or impossible to manage a small works to the greatest advantage unless the works themselves are well and conveniently arranged. When the works are already badly laid out the general arrangement cannot, of course, be altered all at once, except at the great inconvenience of shutting down for some time. In this, as in every other case, sudden convulsions must be avoided at all costs. If the works are to be altered at all, it must be done gradually, as opportunity permits. Thus, if it be desired to shift a large tool into some more convenient place, all the drawings and designs for countershafting and foundations, &c., must be carefully prepared and submitted to the foreman for his approval. The man who works the tool should also be consulted as to the arrangement, as he may have some valuable suggestions to make. There is nothing lost by consulting everybody who has anything to do with the proposed alteration, and there is often much to be gained; besides which it always pleases a workman to be consulted, and gives him a sort of personal interest in things. A workman who is habitually disregarded and treated as of no account comes to look on his job without interest (except on pay day), and if he is a good and reliable man will throw it up on the slightest provocation, well knowing that he can soon get another one. Many workmen are much more susceptible to slights than their superiors, and certainly value their appointments much less. If his suggestions are not accepted, it will be well to explain the reason to him, to avoid offending him. But too much consideration of the feelings and opinions of the men is, if possible, a greater mistake than too little, because it is apt to make them think they are indispensable, and this tends to cause insubordination. A foreman or manager should endeavour to steer a mean

course; that is, to give the men the impression that, while he is firmly resolved to be the master and to stand no nonsense, he wishes to be as reasonable and conciliatory as is consistent with an absolute control of everything. A man who possesses a small amount of tact can do this without difficulty.

When the drawings are ready, the new foundations and bolts should be proceeded with, and any new countershafting and striking gear made and erected, and the new

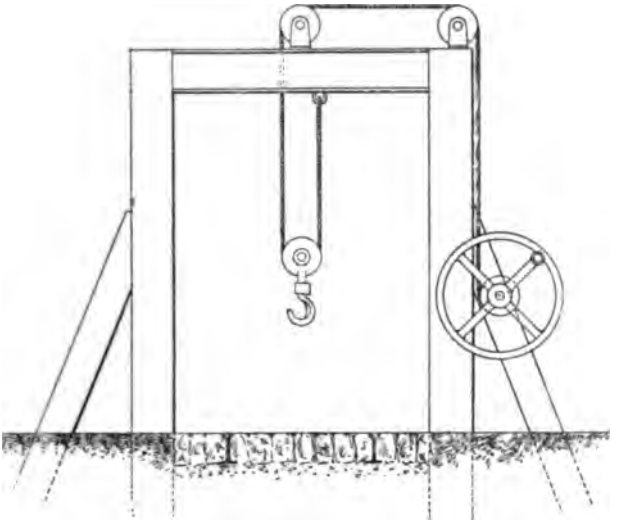


FIG. 1.

belt obtained if required; or, if the old stuff can be used, everything should be got ready to put it up, the work in the tool itself being meanwhile pushed forward as rapidly as possible, so that unavoidable delay in getting the tool to work in its new position will not cause inconvenience in the rest of the shop. Some bank holiday, or some time

when there is not much important work for the tool to do, can then be utilised for shifting the tool itself, which, if the new foundations have been carefully laid out, will occupy but a very short time.

The shape of buildings is so infinitely varied, that it is impossible to do more than discuss the general principles that should be observed in laying out a convenient works. First, as to the approaches and means for getting big work into or out of the shop. If the yard has a railway siding, so much the better. But if not, the approach from the street must, of course, be designed with a view to easy access of heavily laden vans and of loading or unloading them. It is very desirable to avoid the necessity of such vans going into the works at all. The usual plan is, of course, to bring the van or trolley and its load into the works under the traveller, and to back out when the load is taken off. But very often a trolley will arrive with a load at a time when it is very inconvenient to take it into the shop, either owing to the approaches being temporarily blocked with finished work ready to go away, or with stuff which has recently arrived, or it may be at a time when both travellers are engaged. In either case the van may have to wait for hours at the gate or in the yard, and heavy expense may be incurred if the van is engaged by the hour. Again, the struggling of a pair of horses with a heavily-laden van invariably distracts the attention of all the workpeople about the place from their work, and though this may seem a small matter, it has certainly a much greater effect in causing waste of time than appears on the surface. Anything which distracts the attention of the whole shop, such as a party of visitors, especially those of the fair sex, is to be carefully avoided whenever possible. A workman cannot and does not work efficiently if his attention is being continually taken off his work. Very often the approach to the works or the floor of the shop itself is allowed to fall into disrepair, and when the van is taken over it the horses have great difficulty in pulling it into the shop. In many

cases they are even absolutely unable to get inside. Their struggles may result in a fall, in which case the proprietor would be liable for damages. If the horses cannot get it in, a squad of half a dozen labourers will have to be called, with bars and wedges or jacks, which in a small shop will completely denude the place of labourers. This is a great mistake. It means, of course, complete temporary disorganisation of the whole place. If there is any labouring work to be done for any of the mechanics, the lazy ones will "play about" till the labourers come back; the energetic ones will do the work themselves, and perhaps get other highly-paid mechanics to give them a hand. The travellers, if hand worked, will be at a standstill, thus probably stopping one or two heavy machines. All this in addition to the direct waste of the labourers' time and wages. Sometimes the roads are in such a shocking condition, that, when much heavy work is in hand, the mere unloading of stuff costs twice as much in a month as would suffice to put the whole road in thoroughly efficient repair. "Economy" of this kind leads straight to the bankruptcy court. By far the best system is to erect in the yard a bridge crane of the type shown in the sketch, fig. 1, high enough to give sufficient lift to raise the biggest work dealt with clear of the trolley, and broad enough to allow of a very wide trolley running under it with plenty of clearance. Under this run rails sunk to the road level and leading with two or three sidings into the shop. On the rails run several strong, low wagons. If a simple crab is fixed in the shop, provided with a long rope, so much the better. The trolley when it arrives is then taken under the crane and released, another gate being provided, so that there is no need to back out. A wagon is then run underneath and the casting lowered on to it, the slinging chain being left in place. The wagon is then either dragged by the crab, if it is heavy enough to need it, into the shop, or run on to a siding till a more convenient season. Though for this purpose the rails need only run as far as a place where the traveller can get hold of the casting, yet in really well-arranged shops there

is often a system of rails running right round and about the shop; these rails are often of smaller gauge than those already mentioned. They are extremely convenient in facilitating the transport of heavy work from one part of the shop to another.

Lifting Tackle.

Every shop of any size, in which heavy work is dealt with, should be provided with at least two travelling cranes, traversing the whole length and breadth of the shop in which the heavy work is done. It is an intolerable nuisance to have only one even when there is not enough slinging to fully employ two for the whole of the time. When these are driven by power, it is immensely more convenient than by hand. It is, of course, largely a question of what initial outlay is possible. There is very little money expended in an engineer's shop which yields so great a profit as the difference between the cost of a hand-driven traveller and a power-driven one. In addition to the slowness of the former, it invariably involves the necessity of keeping one, and for heavy work two, labourers constantly on the crane for lifting and working alone. The wages of these alone, less the additional cost of deterioration of the power-driven machine, works out at a tremendous rate of interest on the difference in first cost. There is, however, this advantage in certain circumstances which the hand-driven has over the power-driven crane, that if anything goes wrong with the mechanism that puts the power of the latter in or out of gear, a tremendous amount of damage may be done. This, though not likely to happen unless the crane is very badly designed and made, cannot, of course, happen to the hand-worked crane.

The different ways of applying power to travelling cranes are numerous, but for the most part consist of (1) steam engine and boiler on the crane itself, (2) squared shaft, (3) rope drive, and (4) electrical power. Methods which are very useful for stationary cranes, such as compressed air or

hydraulic power, are not well adapted for travelling cranes. Of these, the first is not often used, except for outdoor work. The fumes and sparks or live coals given off from the boiler would be very obnoxious in a closed shop, besides which the inconvenience of keeping the boiler fire going, &c., is very great. It also needs a special man to attend to it. For outdoor work it is convenient in some cases, where there is either no other power to draw on, or where the transmission of such power to the crane would be difficult. It also avoids the waste of power necessary to keep shafting, &c., running when the crane is not in use, and the necessity of exposing shafting or ropes to the weather.

Method 2 is reliable, but is perhaps the most expensive of all in first cost, though its upkeep is not so heavy as the rope drive. It consists of a squared shaft running the whole length of the shop, supported at intervals by sliding bearings in which run parts of the shaft which have been turned. These bearings are automatically moved downwards out of the way by the traveller as it passes by means of inclined planes suitably placed on the traveller. On the squared shaft slides the pinion, which has a square hole in the boss to fit the shaft, and through which all the power passes which is distributed to the hoisting, racking, or traversing gear, through a system of clutches operated by the man in charge of the crane. A good deal of attention must be given to lubrication of the shaft and bearing slides, &c.

The rope-drive method consists of an endless rope running the whole length of the shop, supported on grooved pulleys at intervals, and passing round a grooved pulley on the traveller. This is also a good and reliable method, but its upkeep costs more than that of the squared shaft. The rope usually requires replacing every twelve or eighteen months, but it may be made to last considerably longer if it is taken care of. If it breaks, as it will inevitably do occasionally, it may cause a serious accident if a man gets entangled in it, unless some safety device is added to throw the driving pulley out of gear when the rope breaks. But

even then it is not always safe, as the rope runs at a very high speed. Electric driving is certainly the best of all methods when electric power can be obtained, on account of the ease with which it can be manipulated, besides which a hand gear can be easily added as a stand-by, in case of breakdown.

It is a great convenience when the crane can be operated from the floor of the shop, but it is by no means an unmixed advantage when it involves, as it usually does, chains hanging from the traveller. These are usually so arranged that they move in one line up and down the shop wherever the jockey may be; that is to say, the clutches are fixed on the traveller, and not on the jockey. These hanging chains constitute a very real danger if they are not carefully looked after. One incident witnessed by the writer will serve as an illustration of this. A heavy casting was being taken down the shop by the traveller. The endless chain which operated the traverse accidentally got caught over a projecting part of another heavy casting lying near the gangway. This chain broke off half way up one side. The weight of the other end of the chain pulled the chain wheel round and set the traverse motion in gear, whereupon the casting started to move diagonally across the shop. The craneman was, of course, powerless to stop it except by running to the other end of the long shop to the main starting gear. Before he could get there the casting in its course struck a large fly-wheel which was leaning against another heavy casting. It pulled the flywheel over, and it fell on a large lathe, smashing itself and wrecking the lathe, and the turner only just escaped with his life. It then broke the rope drive, and the rope, becoming entangled with the crane machinery, broke off several teeth of a wheel and bent a smaller counter-shaft, and here the damage, which might have been much worse, ended. This incident illustrates the desirability of having a separate safety clutch, which can at once throw the whole crane mechanism out of gear.

In addition to the travellers, every machine of any considerable size, except the very large ones, which should be served by the travellers, may with advantage have its own lifting tackle. In most cases this consists of only a pair of pulley blocks. These are so cheap that a pair may well be supplied to every machine. It will involve much waste of time if one pair has to serve for several machines. A more or less tired mechanic will waste a lot of time on a hot afternoon in taking down and putting up a pair of blocks, besides which it annoys him to have it to do, and gives him a tangible "grievance," and generally interrupts the smooth mechanical flow of work, which it should be every foreman's aim to secure. Generally speaking, it is very mistaken policy to make any tool in every-day use serve for more than one machine. It invariably leads to friction between the men, and more or less animated discussion, and the loss of time so occasioned is out of all proportion to the trifling cost of such tools. The fitters' benches should likewise be provided with efficient lifting tackle. If they are power-driven, so much the better. The less pulling and tugging a man has to do, the quicker will he do his work. Radial hydraulic cranes are extremely useful for work such as this.

The Timehouse.—This should, of course, be situated close to the entrance to the works, and should be provided with a glass front, so that the timekeeper can see every person who goes in or out of the works. In most small works the timekeeper and storekeeper are one and the same, and the timehouse is also the stores. For reasons to be subsequently explained, this is not a good scheme. The timehouse may, with advantage, be also used as the payhouse where the offices are not convenient for this purpose. It may also be used as works inquiry office. It need not be a large place. Its sole occupant is usually the timekeeper. It should contain the standard works clock, accessible apertures for inserting timechecks and timesheets, a large desk and book-racks for the timebooks, a fireplace, a washbasin, and various cupboards, &c. It is convenient if it also contains means

for opening and shutting the inner door of the works, and windows for communicating with both the outside and inside of the inner door, and telephones or speaking tubes to the various offices. The management of the timehouse will be subsequently dealt with.

Stores.—The storeroom is the centre of the organisation of the whole works. It should also be near the entrance door of the works, and easily accessible from all parts of the shop. It should be a very large, light place, much larger than is usual in small works, and fitted up with a very large number of pigeon holes, drawers, cupboards, and the like, as well as desks and book-racks. It should be surrounded on the side facing the works with glass, so that everybody can see what is going on inside. Without an efficiently managed stores, proper management of the works is a sheer impossibility, and therefore a considerable amount of attention is necessary to the design of the building. The workmen should never be allowed inside the counter which cuts off the store door from the interior. Besides the workmen's door, there is a large sliding door through which trucks may be brought inside the stores. In addition to the ordinary pigeon holes, there must be a considerable number of large, strong compartments for the reception of castings and forgings. Each one of these compartments is assigned to one working number, and all the smaller castings and forgings, &c., are sorted into these as they arrive. This plan not only avoids the necessity of having such things kicking and rusting about the works, but has many other advantages to be shortly discussed. In them are contained castings and forgings in all stages of progress. A proper receptacle must be made for everything that is used in the works, including drawings, jigs, templates, taps, reamers, gauges, mandrels, and tools of every kind. The stores must also contain a washbasin, otherwise the storekeeper, who has to handle a lot of dirty stuff, will find it impossible to keep his books and papers clean. The management of the stores will be fully dealt with in a future chapter.

Foremen's Offices.—These must be situated in conspicuous parts of the works, and raised a foot or two above the floor level, so that each foreman has, if possible, a clear view of the whole of his shop. It is a very great mistake to put the foreman's office in any out-of-the-way corner, in order to save a few pounds in building one in a good position. The foreman should never, under any circumstances, be out of sight of his men. A great many, if not the majority of workmen, make a practice of "easing off" when the foreman is known to be out of sight, and if he has to go into some far-away corner, where he is hidden from view, it not only has this effect, but it wastes his time in going backwards and forwards and that of the men who go to seek him. Each office should be provided with a washbasin, a desk, a rack for drawings, and speaking tubes or telephones to all parts of the works and offices.

The Drawing Office should form part of the works, and not of the offices. There is need for constant communication between the drawing office and the works, and especially the pattern shop, so that the nearer together they are the better.

The Tool Smithy should be near the stores, because all the tools, after being repaired, are to be taken into the stores.

The Pattern Stores should be near the pattern shop, and should be arranged with plenty of shelves, &c., for the orderly arrangement of patterns. The patterns are arranged so that any pattern that is wanted can be found in the course of a few minutes, and taken out without disturbing a lot of others. The number of smashed and damaged patterns caused by a bad arrangement is very great.

Heating and Ventilating.—The shop should be well heated and well ventilated. A very cheap and efficient method of heating, at little or no expense, can be devised by utilising the waste gases and waste steam from the boilers and engines. The amount of work done in the winter is very considerably less than in the summer if the shop is not properly warmed. If a workman comes into a cold shop at six o'clock on a frosty morning, he naturally starts work in a

spiritless fashion, without putting any heart into it. A good workman, who knows he can easily get another job—as a really good workman always can—will not work in a shop where he is frozen to death, so that an insufficiently heated shop will cost the firm many of its best hands. A proprietor loses in this way twenty times the cost of properly warming the place. It is one of the most selfish and stupid forms of false economy to neglect to provide for the thorough heating of the workshop in winter. The steam boilers may, with great advantage, be placed in the main workshop, as they will give off almost enough heat to keep a small shop fairly warm in winter. But if the parts of the shop remote from the boilers are not also heated, the number of men who will find that they have urgent duties which take them down near the boilers or into the smithy on a cold morning before the manager arrives is really astonishing.

The Waterclosets should be placed in such a position in the yard that anybody from a distance can see into them. If they are placed as decency would suggest, many workmen will go there three times a day for a smoke, besides which they are liable to become very objectionable if they are at all closed in. Many large works have a clerk specially for the purpose of booking the time at which men go in and come out, but small works cannot afford a special clerk for this purpose, and must therefore rely on the vigilance of the foremen.

Skulking is a very favourite pastime with many men when the foreman is lax. Special care should be taken that there are no out-of-the-way corners into which men can creep for a *dolce far niente* on a hot afternoon. In one works known to the writer there was a small disused storeroom, which was kept locked up, in a remote part of the works. One of the workmen procured a key to fit the lock, and he and his friends used to retire to this place for half an hour every day, lock themselves in, and play cards and smoke. In the yard of the same works was an old boiler, into which the

men used to creep and rest for half an hour. When there are a lot of fitters or erectors about, a careless foreman often does not notice the absence of one or two, though it is easier to notice a machine-man away from his work, because a machine without a man catches the eye at once.

Arrangement of Machine Tools and Benches.—Owing to the great variation in the shape of buildings, it is impossible to do more in this connection than indicate a few general considerations which should determine the positions of the machine tools in a well-designed works. They will, of course, vary somewhat according to the character of the work to be executed in the shop. Consideration must also be paid to the length and position of shafting and belting necessary for any proposed arrangement, and to a great many other matters into which we cannot enter in articles dealing chiefly with shops already laid out. In general, all tools should be arranged so as to avoid an excessive amount of shifting about of work.

First, as to the heavy machines. These should be put at the end of the shop, or as far out of the way as possible. When a piece of work gets into a large tool, it generally stays there for a week or two before it is finished, so that the more accessible parts of the shop are better reserved for those machines in which the work is being constantly changed. All tools, large and small, of the same class, should be kept together as far as possible, so that when a man working one machine has to borrow a tool from another, he will not be provided with a ready-made reasonable excuse for walking about the shop. This principle should be borne in mind throughout. Most men will take advantage of a good excuse to have a "walk round," which term is, of course, synonymous with a "talk round." When a man has his machine running and his cut on, he has nothing to do until his cut runs out, when, as in England, his union will only allow him to work one tool. He will have a chat at these times in spite of all the foremen in the world, and there is really no particular reason why he should not, provided he does

not stop anybody else from working, and is within a short distance of his machine, so as to give it any attention it may require. He does no particular harm in talking to another man whose tool is at work, but if he happens to be located near a fitter (or any other man whose job requires constant attention), and commences talking to him, he stops the fitter's work, and it will generally continue stopped till the foreman is descried in the distance. In some small shops such machines are, quite unnecessarily, placed near to the fitters' benches. When this is the case, the unwisdom of the arrangement is very apparent to anybody who watches the proceedings for half an hour. The great point is to deprive the machine-man of any pretext for leaving his machine, so that the foreman knows he is idling if he finds him in any other part of the shop. Besides which, it is a convenience to know exactly into which part of the shop any class of work is to be taken.

Machines should not be crowded together nearer than is absolutely necesary. A man is often interrupted in his work if he has to move to allow another man to pass him. He should also have plenty of room to get to the back of his machine. To be crowded up also produces a sense of discomfort, which will make a man dissatisfied with his job without quite knowing why. It is also desirable to avoid making two machine-men work back to back. If the machines can be arranged in rows, so that there is a row of machines between each row of men, and all men face in the same direction, so much the better.

The fitters' and erectors' benches should form only one row, and be ranged along one wall of the works, as far as possible from the machines, especially the heavy ones, and at as great a distance apart as possible; 10 ft. apart is a good distance. To huddle the vices together at a shorter distance than this is very undesirable from every point of view. The men get into one another's way, and either quarrels arise between them or they get into conversation, both of which events are equally prejudicial to the progress of the work. At the

back of the benches should be a good wide gangway, behind which are low tables or stools for castings, &c. The small drilling machines should always be near the fitters' benches, as the fitters, in most classes of work, have to be constantly taking work across to the drillers. It is therefore a mistake to mix up the small drills with the other tools.

Where the heavy erecting shop is separate from the fitting shop, it should, of course, be fed by the travelling cranes—*i.e.*, in the same shop as the heavy tools.

Surface Plate.—A large surface plate should be placed near the door, large enough to take the biggest work dealt with in the shop. It should be strongly ribbed on the under side, and set in cement, perfectly level, at about 18 in. above the floor level. It should be as carefully planed as possible, great care being taken to prevent it warping and twisting. Before being grouted in it should be supported in the same way as it was on the planing-machine table, and very carefully levelled up. It is surprising to what an extent even a deeply-ribbed plate will bend by its own weight, if it is not properly packed up at a large number of points on the under side. Heavy concrete foundations should be used for it, and it should be set up to a good straightedge in every possible direction. It may be tested for twist by means of three long and strong straightedges, two of which are placed level and parallel with one another along each side. This can be done with great accuracy by means of a surveyor's level, and a good spirit level. The third sweeps out a level surface by being placed transversely across these, the distance between the cross straightedge and the plate being taken at a large number of points with a pair of outside calipers. Every casting and forging should be measured over, and lined out on this plate by the marker-off before it is touched by a tool. It is not an infrequent occurrence, in a badly-managed shop, for a lot of work to be put into a casting, only to find in the end that it will not "hold up" in some important dimension, and it has therefore to be returned to the founder.

Many up-to-date employers nowadays provide the men with a room in which they can get their meals, providing boiling water and simple cooking appliances, such as a hot plate or ovens. Many also provide facilities for the men to wash before leaving the works. The lavatory is opened when the bell rings, but not before. If this is not done, men will begin to clean their hands with oil and waste ten minutes before the time for leaving off work. Such arrangements, of course, take up a good deal of room, which, if space is limited, it may be impossible to spare; but the actual expense is trifling compared to the advantage of making the men comfortable. But in any case there can be nothing to prevent a large "set pot" of boiling water being provided, to which the men are not allowed access before meal times, and a hot plate. The workman's ideal shop is one in which he is comfortable when at work (most of them place this consideration before a slight difference in wages), where he is always kept supplied with plenty of work, of a class that he is accustomed to, that he can do well, without any trouble, and without being overmuch worried by a foreman. The better-class specimen does not, as a rule, object to working fairly hard if there is nothing to worry him and nothing to distract his attention, for it makes the time pass quickly. If he can get his meals comfortably and cheaply, it goes a long way towards making him contented with his job. It should therefore be the aim of a manager to study his convenience in this respect, if only from motives of self-interest, especially as, if properly arranged, the cost is a mere trifle. If such things are not arranged for him, most men will make more or less furtive preparations for breakfast long before the hour for that meal. A boy can easily be sent round to collect all the men's cans and dishes, to be put on the hot plate half an hour before a meal. None of the men's time is thus lost, and the men do not waste the firm's time, and often gas, in warming up their own things.

CHAPTER III.

The Drawing Office.

The great majority of small shops, such as we are dealing with, procure their castings and forgings from outside, while they make their patterns themselves. We shall therefore deal with such shops first. To begin with, we shall describe an arrangement whereby all necessary orders are mechanically given out, checked, and counterchecked. We shall start at the beginning, assuming the system in full working order, and, taking a specific order, follow it through the various departments from inquiry to delivery, making such digressions as are necessary for a full explanation. By preserving in this way the continuity of the explanation, the reasons for the various arrangements will be most readily grasped.

Broadly speaking, the objects to be aimed at are :—

1. To let nothing be dependent on anyone's memory.

2. That it shall be possible at any future time for anybody unacquainted with the past history of the firm to find in about half a minute, and with absolute certainty, every possible particular of any order ever executed by the firm, so that the order, or any part of it, could be duplicated by reference to the order number alone.

3. That everything required for going straight on with a job should be promptly and automatically ordered, and obtained without any expensive delays or afterthoughts.

4. That the precise cost up to date of any current job may be found in about half an hour if necessary.

5. That everything coming into the shop may be checked, and proper returns made to the office.

6. That all this may be done with a minimum of trouble and a minimum of bookkeeping, and in such a straightforward way that it does not take a new man half a lifetime to understand the system.

It is for the principal to see that things are so conducted that he is not dependent on anyone's special knowledge. There are many firms into whose works the death or departure of some foreman or other official would introduce chaos indescribable. This is, of course, very much opposed to the firm's interests, and things can never get into this state if the arrangements are properly made.

We shall not treat of pure office work except as to the keeping of costs, which we shall fully discuss in a future chapter. For our purpose the manager will represent the office. It must be premised that if this or any other system is to work satisfactorily everybody must keep to it literally, and it is for the manager to see that it is fully carried out. If anybody fails to carry out his part of it properly, it will, to a greater or less extent, disarrange the whole. Nothing is to be left to chance, and no duties are to be divided. Everybody has some definite duties to perform, and the manager must see that they *are* performed.

We shall now assume that an inquiry, and subsequently an order, is received for two small steam engines, with cylinders 7 in. diameter by 6 in. stroke, and shall follow this order throughout.

The correspondence is, of course, conducted by the manager, as representing the general office. When the inquiry is received with a request for a drawing of the proposed work, he writes an exact description of the drawing he requires to send to the customer in the *drawing-office instructions book*. There will be a considerable number of books to refer to, and we shall refer to them hereafter by letters. D will refer to all drawing-office books, which will be distinguished by Roman numerals. The drawing-office instructions book will be called D I. Store books will be similarly designated S I., S II., &c. Assume, first, that the manager is going to quote a price for a standard engine, of which the firm make a specialty. There is then, of course, no difficulty in designing or estimating. The manager can tell by reference to the cost

book precisely what the engines will cost the firm to make, and he quotes the highest price he thinks he can get. The book D I. is ruled as follows, and the manager fills in the first three columns as shown. This book is written up every morning by the manager after reading the letters, and at once sent into the head draughtsman.

BROWN AND CO., Engineers.

DRAWING-OFFICE INSTRUCTIONS BOOK, D I.

Date.	Drawing required.	Time when required.	Completed.	Inspected by
1897. August 21.	Blue print off standard 7 × 6 engine tracing.	To-day, August 21, not later than 4-30 p.m.	3-30	J. B. W.

The head draughtsman gives the order to a junior, to take the required blue print.

In order to find the tracing of which a print is required, the junior refers to the Index Book, D II., which is a large book containing indexes of all the drawings possessed by the firm. A part of the book is set apart for standard tracings. The information about the drawings contained in the index should be very complete. The standard tracings may be thus indexed :—

DRAWING-OFFICE INDEX BOOK.

BROWN AND CO., Engineers.

D II. S Standard Tracings.

No.	Description of tracing.	Date when made.	By.	Detail drawing numbers.
27	7 × 6 standard vertical engine, pressure 180 lb. per sq. in., 250 revs., 30 H P.	27, viii., 92	E. W. Robinson	$\frac{1}{17}$, $\frac{1}{2}$, $\frac{1}{7}$, $\frac{1}{9}$

Several lines should be left in the index between each entry, to allow of the insertion of remarks, corrections, &c.

The standard tracings are to be all very carefully made, and more or less elaborately decorated with frame lines, &c. A slovenly drawing gives a customer a bad impression of the firm. They should all be made on tracing cloth, and not on tracing paper. The latter is easily torn, and the cost of making another tracing to replace a torn or crumpled paper tracing is out of all proportion to the difference in cost of material. Suppose a tracing takes a day and a half to make, the wages of the tracer being 25s. a week. The cost of the workmanship is, roughly, 7s. The cloth costs, perhaps, 9d., making a total of 7s. 9d. For a difference of 6½ per cent it is certainly not worth risking having to spend 7s. 3d. every time the tracing is copied. Yet many firms use only paper for such work as this, on the ground of "economy." This is the kind of economy which must be most strenuously guarded against.

On every tracing is—

(1) A neatly stencilled title, which is, for uniformity, put on the same part of the tracing in every case.

(2) The number of the tracing, thus, S 27 ; S referring to the standard portfolio of tracings, and 27 indicating the position in which it is to be found in the portfolio.

(3) A black square or oval, which will come out white in the blue print. This space is for the date stamp, which reads :—

Brown and Co.,
Engineers,
Tutbury.
August 21, 1897.
Forwarded to
Messrs. Jones and Co.

(4) Scale of the drawing—thus, "3 in. = 1 ft."

When the blue print is finished it is taken to the head draughtsman for his inspection, and sent by him into the manager's office. He then fills up columns 4 and 5 in the

book D I., and enters in the Drawing-office Journal, D III., the sending out of the print, thus :—

DRAWING-OFFICE JOURNAL, D III.

Date.	Drawing sent out.	For
Aug. 21	Blue print of S 27	Jones & Co. inquiry.

The tracing is then put back into its place, and the drawing-office connection with the matter ceases.

The drawings and tracings are kept unfolded in large portfolios, with a label pasted on the back, indicating the number of the portfolio and its contents. Fire-proof safes, with horizontal shelves, are used for storing these portfolios.

If, however, a fresh preliminary design is required for some reason, the process is not so simple. The manager will require more information from the drawing office in order to be able to make a reliable estimate. He would enter up the book D I. as follows :—

Date.	Drawing required.	Time required.	Completed.	Inspected by
Aug. 21	Blue print of 7 × 6 engine, bed plate, with hood, and bolt holes to sketch sent, T 4871, to couple to existing dynamo; pressure 180 lb. square inch. Revolutions 250. Large bearings, intensities not greater than crank pin, 400 lb. square inch. Main, 200 lb. square inch. Coupling forged solid on shaft, flywheel, no outer bearing. Supply weights of castings, forgings, and brasswork, and state what pattern making required.	Saturday, at 1 p.m.		

These instructions should embody the whole of the requirements mentioned by the customer in his letter. The manager also sends in to the drawing office any tracings, &c.,

received from the customer, which are immediately numbered, indexed, and dated by a junior, and when put away go into the general portfolio of miscellaneous tracings in their proper order. The head draughtsman then makes the necessary calculations as to sizes of bearings and ports, &c., and considers what will be the cheapest way of making the engine, and hands suitable general instructions to one of the draughtsmen to make a preliminary design, of course emphasising the essential requirements.

The first thing the draughtsman has to do is to consider what existing patterns can be brought in, with or without slight alterations. To do this he refers to the Pattern Book, D IV., kept in the drawing office, containing a classified, descriptive, and complete list of all the patterns possessed by the firm. This book is ruled as follows :—

Class.	Size.	D. No.	Weight.	No of pattern.	Remarks.	Date.	Used for
			ct. qr. lb.				
Cylinders	7 × 6	$\frac{16}{1276}$	2 1 7	872	Altered for w.n. 2876 to $\frac{16}{205}$, on 3, viii., '95	23, ii., '02	2777
		$\frac{16}{2062}$	1 3 22				2798
		$\frac{16}{205}$	2 2 2		Altered to $\frac{16}{205}$ for 2972, on 22, v., '96		2876
							2972
					Damaged by fire in stores.		2998
					Renewed for 2998 to $\frac{16}{205}$, on 17, vii., '96		

The draughtsman has thus a complete description of the present state of all patterns which can possibly be used for the job. The first two columns explain themselves; the third gives the information that the drawing of the pattern, as existing at present, is in portfolio 16, number 205; the fourth column shows the actual weight of the casting; the fifth column gives the number of the pattern, and shows where the pattern is to be found in the pattern

stores, as will be shortly explained; the sixth gives a complete history of the pattern since it was made. Thus, the first remark shows that it was originally made to drawing $\frac{1}{17}\frac{6}{8}$ for working number 2,777, and was altered on the 3rd of August, 1895, to drawing $\frac{2}{20}\frac{6}{3}$ for working number 2,876. This information, though not at present of any value (except in so far as it shows that the pattern can probably easily be altered back again to $\frac{1}{17}\frac{6}{8}$), was of considerable value to the draughtsman who designed $\frac{2}{20}\frac{6}{3}$ on May 22nd, 1896. It would also be of considerable value if a duplicate order were ever received for either working number 2,777 or 2,876. The seventh gives the date when the pattern was made, and the last a list of all working numbers for which it was used. This book must be filled in by the head draughtsman from a sheet to be shortly described, on which he sends out any instructions to the pattern-shop foreman relative to any of the patterns. It can be kept with very little trouble, and its value to the firm is immense, as, if properly kept, it will often save a tremendous lot of pattern-making. The proper method of keeping it so as to ensure its being accurate will be presently explained. There is also an index of the patterns, *in numerical order*. This need only consist of three columns, thus—

No.	Description.	D. No.
872	7 × 6 cylinder.	$\frac{1}{17}\frac{6}{8}$

The draughtsman has thus a birdseye view of the whole of the pattern stores, and he has to determine whether any of the patterns in existence will suit the purpose, and with what alteration, if any, and he makes his preliminary tracing to suit. He may, if he pleases, go to the pattern stores to see the pattern itself before deciding to use it. He does the same with all the rest of the castings, and

calculates the weight of any castings off proposed new patterns. The head draughtsman supervises these proceedings at all stages, and gives any further instructions that may be called for. No great amount of detail is shown on the sketch. It is an outside drawing only, and is merely provisional, but should be true to scale. It should have marked on it in pencil the numbers of the various detail drawings from which it is compiled, and the main dimensions, such as distance apart of main centre lines, length of connecting rod, length over all, &c. The sketch should be lined in in clear pencil lines, precisely as the tracing is to be. Nothing should be left to be designed by the tracer. When the pencil sketch is complete, the head draughtsman goes over it and checks it with the instructions in the book D I., and if it corresponds it is given to a junior, who numbers it, giving it the next number in order to the last sketch that was made, and enters it into a *Sketch Index Book*, D V., which is a list (not classified) of all unfinished sketches. Thus—

No.	Date.	Sketch of	By	Tracing No.
2792	August 25	7 × 6 engine, with hood and bolt holes to tracing 4781, 180 lb., 270 revs.	J. R. Thompson	4782

When the sketch is finished, and before being traced, it may be shown, if necessary, to the manager, to see if it corresponds with his ideas. If so, the junior traces it, numbers the tracing, puts the title on as before, and indexes it in the Tracing Book, D VI. (which is a consecutive unclassified* list of all tracings made), with the reference to the sketch from which it is traced.

*It is convenient to have a separate classified index of these tracings and sketches, so as to facilitate the finding of any one of them from the description alone. Inquiries often come in embodying requirements which would be satisfied by a tracing already in existence. The making of a fresh preliminary design is thus avoided.

TRACING BOOK, D VI.

Date.	No.	Tracing of	Reference.
August 26, '97.	4782	Special 7 × 6 engine, with hood and bolt holes to tracing 4781. 180 lb. per square inch, 270 revs.	Sk. 2792

He then takes a blue print of it, and proceeds precisely as before. The draughtsman then proceeds to write out all the information required by the manager, thus :—

TRACING 4782.

	cwt.	qr.	lb.
Weight of iron castings	11	2	0
Weight of forgings	4	3	0
Weight of brass and g.m. castings	0	3	12

PATTERN-MAKING.—*Bed-plate* pattern to be altered in bolt holes, and hood added from $\frac{7}{8}$ to present tracing. Bearings lengthened. Also to be handed.

Cylinder.—To be handed. New core boxes required for cylinder ports. Alteration to flange of valve chest from $\frac{1}{2}\frac{6}{6}\frac{5}{5}$. New valve. New bearing caps. All brasses stock patterns.

The manager is thus in possession of all the information necessary to base a reliable estimate on. If he is in doubt as to the amount of pattern-making necessary, he can consult with the foreman pattern maker, who ought to be able to tell him very nearly the length of time required. If it is necessary, either the draughtsman or the manager can go with the foreman to see if the patterns can be easily altered, or whether it would be cheaper to make new ones. A great many firms make a practice of hacking their old patterns about, in order to save money, in cases where, in fact, it would be much cheaper and better in every way to make new ones. On such a point as this the foreman pattern maker, if he is fit for his position, will generally be able to give very reliable information, and should always be

consulted, as not only does his experience of necessity make him more competent to express an opinion than anybody else, but also, if he has fixed the time himself, he will generally, for his own credit's sake, take care that it is not exceeded.

It is in general a great mistake to tamper much with a pattern which is constantly in use, for, in addition to the cost of altering the pattern, there is the subsequent cost of altering it back again to be considered, as also the damage consequent on pulling it to pieces. Indeed, many of the best firms will not allow a pattern to be altered at all. If it will not come in exactly as it is, a new one is made.

All calculations and notes made by any draughtsman should be made in books supplied by the firm, and should be preserved, labelled, and dated clearly, so that they can be referred to at any future time. It invariably happens that when these are made on loose pieces of paper they are lost, and are wanted afterwards and cannot be found. They should be made so that anyone can afterwards follow what they mean, and not be an unintelligible jumble of figures. Everything is thus left in such a state that the job could be taken up where it was left off by a party of strangers who had never been in the place before, and who could not possibly mistake the meaning of anything.

When the order is received from the customer, the manager writes it out in full detail, with an accurate description of everything the customer requires, referring to the tracing which has been approved of. If the customer desires alterations made from the tracing, it may be necessary to send him a fresh tracing embodying the desired alteration. These are easily made on the sketch, which can be at once found from the book D VI., the manager giving the order to the drawing office by means of the book D I. If the alterations are only trifling, the original tracing may be used, ink lines being easily erased by a wet camel-hair brush, some clean blotting paper, and a piece of indiarubber. A skilful draughtsman can make considerable alterations on either a

tracing or a blue print without it being very apparent that they have been altered. But, unless it is very neatly done, it is a mistake to send it away. A customer is always unfavourably impressed by an untidy drawing. If one is altered, the other must be altered to correspond. It is irritating to a customer to have any of his stipulations, however trifling, disregarded. Nothing pleases him more than to have his particular fads carefully observed, however absurd they may be. The writer once knew a customer who was deeply offended because the firm from whom he had ordered a pair of engines neglected to deeply chamfer the connecting rod and crosshead bolt heads, according to an alteration made by him in pencil on the preliminary blue print. The custom of the firm was to round them, and by a trifling bit of carelessness they were drawn rounded on the shop drawing.

One order usually consists of several parts, the cost of each of which must be taken separately; so that the order numbers and working numbers are best kept separate, there being several working numbers to one order number.

The cost clerk numbers the orders as they are received, and assigns working numbers to the various parts, according as he desires to keep the costs separately, and copies the order as written out by the manager into a book specially kept for the purpose, and also cyclostyles it, taking six or seven or more copies, as may be required. One of these is sent to the head draughtsman, each of the shop foremen, the storekeeper, the cost clerk, and two or three kept in hand to replace lost ones, if any. The firm supplies special paper clips to fasten these orders together, and the clerk who fastens them together should cut away parts of the sheets, on the thumb index-book principle, so that any sheet can be turned up at once, without any waste of time. These order sheets read as given on page 32.

It is a well-known practice in the engineering trade to promise delivery long before the goods can possibly be ready. This is a great mistake. If a firm is known to make a

practice of being promptly up to time, they will often secure orders which they would not have secured otherwise.

The head draughtsman receives his orders to proceed with the drawings from the manager, and he distributes the work as he thinks fit, giving it, if possible, all to one man, so as to save confusion.

ORDER NUMBER 7,275. DATE: AUG. 29TH, '97.

Working number.	Order.	Delivery promised by.	Order completed	Remarks.
15,760	Two 7 × 6 engines, right and left hand, to our tracing 4,782. Hood and foundation bolts to tracing 4,781, sent us. Pressure, 180 lb. Revs., 270 per minute. Coupling forged solid with shaft, large bearings, as per our tracing 4,782. All parts to be absolutely interchangeable, to satisfaction of inspector. Flywheel, but no outer bearing. Piston rod and valve spindle nuts to be of gun metal. Other details exactly to tracing.	Jan. 30th, '98, under penalty.	Jan. 14th, 1898.	Customer very particular to keep to tracing sent, exactly.
15,761	Two stop valves, 2 in. diameter, Admiralty pattern.			
15,762	One complete set of spare details to fit either engine, consisting of piston, piston rod, and crosshead, with pin, connecting rod, crank shaft, eccentric sheave, strap, rod, valve, and spindle.			
	Also an additional set of spare brasses for crosshead pin and crank pin and main bearings.	Jan. 30, '98.		
15,763	Packing, delivery, and erection.			

The draughtsman takes the sketch, and looks out the various drawings noted on it, which are to be the basis of his design.

Here it may not be out of place to enter a protest against the practice, so common in many firms, of endeavouring to save money by making one drawing serve for half a dozen different jobs. One frequently sees working drawings covered all over with blue and red lines, and figures, with

such remarks as: "To red dimensions for 6 × 6." "To blue dimensions for 7 × 7." "Dimensions in black, underlined with red, are for 200 lb. per square inch." "Alterations sectioned in red lines are for working number 2,498," &c., &c.

A chaotic system of this kind is sure sooner or later—and probably sooner than later—to end in disaster. Some bad and ruinous mistake cannot fail to be made, the responsibility for which should lie entirely with the manager who sanctions such an absurd system. If a job will not stand making a proper drawing for, it is not worth taking. If it has to be taken at a low price in order to secure a customer, then the loss on the job is the price that has to be paid for that customer; but to let the price be the introduction of chaos into the drawing office, and to disorganise the whole system in order to make one particular low-priced job come out on the right side, is a stupendous piece of folly. But it would be going to the other extreme to make a new drawing for a trifling alteration, such as the shifting of bolts or putting a facing on, or similar things. When a drawing is once made, that drawing must be kept as it stands, and not altered on any account whatever. It is the only record possessed by the firm of what was supplied to one or more different orders. If it is once altered for any other job, then it is no longer a reliable record. If it is not accurate, and absolutely reliable, it might as well be torn up; then, at least, it will not deceive anybody, and any proprietor who allows his drawings to be tampered with in this way fully deserves all the worry, annoyance, and loss that will assuredly come on him sooner or later.

The proper way to make any small alterations in a pattern for a particular job is to make a separate drawing of the alteration. It may even be on the same paper under certain circumstances, if there is room enough, but it must be a separate drawing. It must be distinctly labelled what it is, and some distinctive reference mark or letter put on it, so that in the Record Book, D VII., shortly to be described, the alteration may be definitely and certainly referred to. But

it is far better to put it on a separate paper, and enter this in the book as a new drawing of an alteration to the other drawing. If any considerable alterations are to be made, there must be a new drawing throughout. This is far better, and in the long run cheaper, than fiddling about with half a dozen scraps of paper, each involving some alteration, and each one trebling the risk of mistake. If a workman—who is not (as draughtsmen are apt to forget) as familiar with the job as they are, nor as familiar with drawings and their subtleties—makes a mistake through taking a dimension off one drawing when he ought to have taken it off another, even although he may have had verbal instructions to that effect, he cannot be reasonably held responsible. The draughtsman who made such a bungle possible is the person responsible for the mistake. The workman's job should be absolutely straightforward. The only instructions a competent workman should require are: "Here is the casting, and here is the drawing, and here are the gauges." If more instructions than these are required, it is generally a sign that the drawing is defective.

Before the shop drawing is commenced the draughtsman must be provided either with all the actual fittings required for the job, or with exact drawings of them. The reason for this is that he may be able to make his design so that they can be put on easily. If this is not done the draughtsman is not only unable to finish the design as it ought to be finished, but also he is apt to put in his bosses too small or too large, or in situations where it is impossible to screw the cocks on, or where the cocks, when put on, will foul something else. Firms sometimes make a practice of not obtaining these things till just before the machine is finished. The idea of this insane practice is to avoid laying out money until it is necessary, and the result of it is that the cost of alterations and waiting for the things to come is invariably greater than the whole cost of the things themselves. This is another example of the sapient "economy" that we have protested against so often.

General arrangement.—After the detail drawings are all finished in pencil, a general arrangement should be made of the whole plant, as ordered, drawn carefully to scale, and showing every single thing that is to be supplied by the firm, and nothing else. This is often omitted in small works, and the omission always leads to much inconvenience, and often to grave mistakes being made. Without it the foreman has to be continually sending for the draughtsman, to verify such things as the handing and asking for instructions about the various fittings. It is marked with all the leading dimensions, such as distances apart of centre lines, position of steam and exhaust branches. Any auxiliary apparatus, if not drawn in detail, should at least be clearly indicated. It should be full enough to show the foreman clearly what he has to make and how it is all arranged, how the oil pipes run, and so forth. All the detail drawing numbers should be marked on it. It should, in fact, be the shop index of the whole job, and sufficient to explain to the erector what he has to do, without his having to ask any questions. On this the draughtsman must test whether every part of the engine works without fouling any other part. Thus he makes an outline drawing on a piece of tracing paper of the piston, rod, and crosshead, with all nuts and bolts in place, to the same scale as the general arrangement, marking the centre of the crosshead pin as the intersection of two centre lines. Then he marks on the general arrangement the top and bottom of the stroke of this pin, and, placing the tracing on the drawing in the two extreme positions, tries whether the piston fouls either cylinder cover, and whether the crosshead or its bolts fouls the gland or the gland studs at the top of the stroke, and whether the foot of the crosshead reaches its correct position at either end of the stroke. He does the same with the connecting rod drawing on the end elevation—a section of the bed plate in the plane he is considering—and placing his tracing of the connecting rod with the top centre on the line of stroke, and the bottom centre on the path of the centre of the crank pin all

round the circle, makes sure that the crank-pin end does not foul the bed plate, and the body of the rod, or the fork, does not foul the edge of the slide. He does the same with every moving part of the engine, including crank shaft and valve gearing. When any part is tested in this way, care must be taken that the section drawn on the end elevation is in the same plane as the part that is being tried over, also that *every* section of the moving part is always clear of the corresponding section of the bed plate in all positions. By similar methods he must also make sure that every part can be conveniently taken off, or put on, without disturbing any other part. The writer has seen designs in which it was necessary to take the cylinder off the bed plate in order to get the cover off or on. These checks on figure calculations should never be omitted, as they are of the most extreme importance. The value of a draughtsman very largely depends on the thoroughness with which he carries out such tests as these. When he has finished with it, all his dimensions are checked by the head draughtsman, and ticked off as checked, and any omitted dimensions inserted.

When the drawings are all finished accurately to scale, in pencil, they will be thoroughly overhauled in every part by the head draughtsman, who checks all calculations, tries whether they agree with the specification in every respect, and with the preliminary tracing, and whether the design can be improved or cheapened in any way. Though it is not right theoretically, yet it is a very good plan to let the head foreman overhaul all pencil designs before being traced. If he is a thoroughly good man, he will often be able to make really valuable suggestions. If any important difference of opinion arises between him and the head draughtsman, the manager may have to act as referee. Theoretically, of course, the foreman is a subordinate, whose duty is to supervise the carrying out of the head draughtsman's instructions as given in the drawings, but in practice he is likely to be a much better authority than the latter or anybody else on the subject of cheapness of production and

difficulties of execution. If the two cannot work well together, the manager must choose whether to decide all disputed points himself, or to replace either the foreman or the head draughtsman, or to give one or the other the premier position, but most head draughtsmen would refuse to be under the direction of the foreman, and if he desires to retain both the head draughtsman and the foreman, the former must be given absolute responsibility for the drawings. The head foreman can always bring discredit on the drawing office if he is anxious to do so, and can often prevent costly mistakes by timely intervention before a job has got too far. But he will not usually trouble to do this if the designs have been made over his head, and against his advice, especially when, as is not infrequently the case, he is likely to be told to mind his own business if he does so. It is very important that the drawing office and the shop should work harmoniously together.

On the finished detail drawing should be shown every single detail of the work, as finished. Every trifle should be marked; such things as radii of fillets, position of odd bolts and studs, should not be omitted, even though they may be of no importance. As we have said before, the workman should have nothing to do but follow the drawing blindly, which should be in itself a complete answer to all possible questions. Every question that arises, or mistake that is found, involves a waste of the workman's time. He has to see the foreman, who sends or takes the drawing up to the drawing office, the workman usually waiting meanwhile for its return with the required information. It wastes the head draughtsman's time, since he has to look out the original tracing, and alter three or four or more drawings or blue prints, to make them all correspond. Before being traced, the pencil drawing must be completely finished, exactly as it is intended that the finished drawing is to be, with dimensions all marked in pencil, in dot and dash lines, so as to be easily distinguishable from centre line. They can then be inked in by a

tracer, and coloured, &c., but not till after the work they represent has been finished. Slight alterations of the drawing will sometimes be found necessary, not because of mistakes (though these will at times creep in in spite of all the care in the world), but because castings will not always "hold up" to drawing sizes, and for other reasons. The drawing can then be altered to suit without scratching it all to pieces. Some firms do not ink in their drawings at all, but keep the tracing as the standard drawing-office copy. This certainly saves money, but it is a matter of opinion whether it is a good plan. No trial pencil sketch can be made on the cloth tracing, and it is convenient to be able to sketch on the finished drawing when alterations to the pattern are in contemplation for another job. It is hardly possible to bestow too extravagant care on making sure that the drawings are all right. All working drawings should be very fully dimensioned in clear, bold figures. The very small figures often put on a working tracing by draughtsmen who have more idea of beauty than utility, may look very pretty to those who have good eyes when the tracing is nice and clean, but when it gets into the shop as a photo print, and gets a thick coating of black grease all over it, and has to be read by an old man in a light that is often none too good, the bigger and thicker the figures are the better. In fact, prettiness of a working tracing should not be in any way considered. The all-important features of a working drawing are clearness and accuracy. A draughtsman who is accurate will usually (though not always) be neat. But he can be neat without being "finniking." The lines should also be thick and clear, and the dimension arrowheads strong and pronounced. As regards dimensions, every view of a machine should be completely dimensioned—that is, almost every line on it should have at least one arrowhead running to it, and sometimes two, one giving the distance from the centre line and another the detail dimension. Of course, in many cases this latter would be absurd. All

circles on the drawing should have their radius given, and in many cases the position of their centres. If it is possible to make a true copy of each view of a drawing without laying a pair of dividers on it, it is completely dimensioned, but, generally, not otherwise. It should not be necessary to look on a plan for a dimension that does not appear on the elevation, or *vice versâ*. Again, dimensions should be arranged on some sort of system, and useless dimensions should not be inserted, as they confuse the drawing. All dimension lines should be kept in rows as far as possible. In putting in a dimension the draughtsman should consider for what purpose the workman will require it, and how he will use it in marking off, &c. No attempt should ever be made to crowd figures into a narrow space, as they can always be transferred to a clear space by means of suitable "carrying" lines. Every casting shown on a detailed drawing should be labelled with the number of the pattern to be used for it. It is necessary to reiterate the immense care that must be exercised in checking a drawing. One single wrong dimension may easily cause a great loss of money, and no precautions in reason can be too elaborate to make sure there are no mistakes. A mistake on a drawing before it gets into the shop may be rectified by altering a figure. Afterwards, it may be necessary to throw away a finished casting in order to rectify it.

Great care must, however, be exercised in making all drawings *exactly* to scale. This is impossible unless all drawing boards and squares are exactly true. The moment any inaccuracy is discovered in any of them, it should be sent to the instrument maker for adjustment.

When the pencil drawings have been finally passed by the head draughtsman and head foreman, they are handed over to a tracer to trace on cloth. No colouring should be put on these tracings, but they should be sectioned with ink lines thinner than the working lines, and the tracing should be an exact reproduction of the pencil drawing, both as to position of

dimension lines and in every other respect, and carefully checked by the draughtsman with the original. In the tracing, centre lines are shown dotted, and dimension lines dot and dash. Blue and red lines on the tracing do not show on the photo print. Its title and drawing number should be stencilled on it, as well as the scale and date. There should be one uniform part of the drawing for all titles. No original tracing should ever be allowed to go into the works. The best form for works drawings are clear black on white photo prints, pasted on sheets of stiff cardboard, and bound round the edges with canvas. They are better than blue prints, because the figures are clearer when smeared over with the dirt with which they will subsequently be covered. They are provided with a strong string tag for hanging up, and when they are known to be accurate, and are standard drawings, they may be covered with thin transparent varnish. The common method of sending into the shops cloth tracings rolled on sticks is an unmitigated nuisance, and is bad in nearly every respect. It is by far the most expensive method. When the drawing has to be renewed a fresh tracing is necessary, with the attendant risk of inaccuracies. When a workman is using one, and wishes to keep it open, he has to lay it down on a dirty table, probably covered with grease, in which it gets soaked, and it seems to float all over the shop, and get in everybody's way. If it gets at all crumpled, as it is sure to do, it is quite illegible, unless it is held up to allow the light to shine through it. At night time this means holding it against a gas flame, when it often gets on fire, and a great hole is burnt into it. Some workmen will burn them purposely when irritated at being unable to read the figures. When anyone is looking for any particular drawing among a bundle, it is necessary to either unroll one after the other, and then roll them up again, or to scrape the dirty grease off the sticks to see what the number is. If the numbers are stamped on, either the wood breaks away where the figures are stamped, or the figures get filled up with dirt and cannot be read.

The rolls easily fall behind benches, or into any small aperture, where they may be undiscovered for weeks; or, if a workman wants to take one home, either for some purpose of his own or because of some grudge against the firm, he can easily stick it up his coat sleeve and walk out unperceived, or destroy it in some other way. With such an accumulation of disadvantages, it is astonishing that any firm will use drawings of this kind. By the photo-print method copies can be multiplied or renewed at any time, at small expense. They are convenient to handle, easy to read, easy to find, and easy and cheap to renew, if lost.

Three of these photo prints should be made from each drawing, except the general arrangement, of which only two will be necessary, and one of each being unmounted, these being for the foreman's office. When mounted and finished, the others should be sent to the stores, where they are placed on a rack till required, all the drawings for one order number being kept in a separate compartment, labelled with the order number and the working numbers, until the job is put in hand in the shop, when they are sorted into compartments labelled with the numbers of the books from which the respective drawings are taken. Every photo print sent out of the drawing office is entered in the book D III., along with its destination. A list of the working drawings (D VIII.) in the shop is also kept in the drawing office, and the entry is made on this list at the time when the drawing is sent out. Small alterations in these drawings may be made by pasting an appropriately labelled and printed piece of photo paper on some spare corner, to correspond with the alteration made on the finished drawing, as above described, the addition being noted in the book D VIII. When the alteration is made on the drawing, it should also be made on the tracing, so that the standard office drawing and the tracing from which the working prints are taken always correspond exactly.

When an order is received for a job of which there is a working drawing in the shop, the head draughtsman should

always compare it with the original before sending into the shop instructions that it is to be used. Some previous draughtsman may have neglected to make corresponding alterations in the works and office copies.

Ordering.—The drawings having been finished, the next thing to be done, before the orders to proceed with the job are sent into the shop, is to make sure that everything necessary is ordered. The waste of time that is caused by the omission to order or procure whatever is necessary is very great, and a proper system of ordering thoroughly carried out will save a very large percentage of the cost of fitting.

The drawing office is provided with a certain number of printed forms which have to be filled up by the draughtsman, who is, of course, better acquainted with the job in its initial stages than anybody else. All the forms belonging to one job, when filled up, are pinned together and sent first into the general office, and afterwards to the store-keeper, and are kept by him while the job is passing through the shop. The object of them will appear as we proceed.

The first form (A) is a sort of *résumé* of the whole job. It is printed as follows :—

Form A.

BROWN AND CO, Engineers, Tutbury.

Date of order .....
Order No. .....
Working Nos. .....
Date delivery due .....
Order—

General arrangement No. .....
Detail drawing Nos. .....

Remarks—

The draughtsman fills in the particulars indicated. In the space labelled "Order" he writes a condensed copy of the cyclostyled order sheet. He also gives all the drawing numbers and the subject of each, thus: "7 × 6 cylinder 16/208."

The storekeeper is thus provided with a list of all the drawings belonging to that order. If any of these are old drawings which have been used before, he collects them and puts them in one of the compartments of the drawing rack, ready for use when required. The foreman knows precisely what drawings to work to, and the responsibility for any mistakes in the drawings rests entirely on the drawing office. The method of dealing with the drawings in the shop will be treated of when considering the management of the stores.

The next form (B) consists of instructions to the pattern-maker foreman, and tells him what castings are required, what old patterns to bring in, and what alterations are to be made in them, and which castings require new patterns. It may be necessary to consult the pattern-maker foreman in filling in this form. The form is printed and filled up as shown on page 44.

If the pattern required is a new one, the fourth column is filled in with the number next in order to the last pattern that was stamped. Thus, before this order was started on, the total number of indexed patterns possessed by the firm was 1,944. When appropriating a new number to a particular pattern, the draughtsman must make a note of it in the Pattern-book index—*i.e.*, the *numerical* index to book D IV.

It has before been remarked that the pattern-maker foreman should be often consulted in deciding what to do in regard to the patterns. Pattern making is a special branch of engineering of which draughtsmen and managers are often a good deal more ignorant than they ought to be. Great care must be taken, in making out this list, that every single casting required is entered, however small and

insignificant. It is just the small ones that are liable to be overlooked.

Form B.

BROWN AND Co., Engineers, Tutbury.

Pattern Shop Instructions.

Order No..... Date.....

Working Nos.....

Number required.	Description.	W. No.	No. of pattern	D. No.	Old, new, or alteration.	Remarks.	Completed and checked.
2 (handed)	Cylinders 7 × 6..	1560	872	16/208	Alteration.	To be handed—New core boxes for cylinder ports. Alteration to flange of valve chest.	
2	Valves	Do.	1945	16/208	New.		
2 (handed)	Bed plates	Do.	455	18/175	Altered.	To be handed—Bolt holes altered. Bearings lengthened. Hood added.	

The next form to be filled up is a complete list of all the iron castings required for the job. In the great majority

of modern firms a specialty is made of a particular class of work. A general engineering establishment has but little

Form C.

BROWN AND CO., Engineers, Tutbury.

Order No..... Working Nos..... Date.....

Engine Castings (Iron).

Number required.	Description.	D. No.	Pattern sent away.	To.	Delivery due.	Received.	Weight.	Finished machin'g
	Cylinder							
	Cylinder covers....							
	Valve-chest covers..							
	Main valve.....							
	Etc.							

chance nowadays of being a financial success, because everything it could make could be turned out much more cheaply from an establishment which made a specialty of that

particular class of goods. For illustration's sake, we shall assume that Messrs. Brown and Co., of Tutbury, make a specialty of engines. There will then be a form on which is printed a complete list of the castings required for an engine of their ordinary type. This list reads as shown on page 45.

The draughtsman fills up columns 1 and 3 from the drawings, and the general office and the storekeeper fill up the others at the proper time.

The next list (D) is a precisely similar one of the brass and gun-metal castings required. Plenty of space is left at the bottom of each sheet for extras. In all cases the draughtsman must take extreme care that nothing is omitted. There is a double reason for this extreme care: firstly, that any omission causes delay and expense in the shop; and secondly, that if the firm makes an agreement with the founder for a certain batch of castings or forgings at a certain price, the latter may increase the price for any extra forgotten castings. Then there is the extra expense of cartage of pattern and casting backwards and forwards, and the general confusion that will be inevitably introduced by the arrival of an isolated casting.

The next form (E) is a printed list of forgings required. It is precisely similar to Form C, except that instead of the column for "Pattern sent away," there is one for "Forge sketch sent away," which must be filled up in the office. The forging sketch is a blue print off a forge tracing, which is made in the drawing office by a junior, and then carefully checked by the head draughtsman, who makes sure no item has been omitted. It is customary with many firms to make these tracings not to scale. Indeed, many draughtsmen seem to take a pride in making the forge tracing as unlike the actual forging as possible. This is a mistake. A tracing to scale takes very little longer to make than one which is not to scale. There is less liability to mistakes in a scale tracing. It is not necessary, of course, to draw in any fine detail in this sketch; but if the forgeman knows what the

forging looks like when finished, it is a help to him. Of course, it must be fully dimensioned, in addition. The blue print when made must be fully labelled with (1) the name of the ordering firm, (2) the number of the forge tracing (these are best kept by themselves, and a separate index kept of them), (3) the description of the forging, (4) the number required off each sketch, (5) the date, and (6) the working number of each forging.

The last three items should not be put on the tracing itself, but should be replaced by black patches, which, of course, come out white in the blue print. The required particulars are then written in black ink, or stamped on the white spaces left. The object of this is greater clearness, for if the tracing paper happens to be wrinkled or blistered at the spot where these all-important particulars are written, there is a blur on the blue print, which the forgeman may misread either accidentally or purposely, and send in more forgings to one sketch than are actually required. Another reason is that if another order be received at any future time for one or more of the same engines, it is merely necessary to take another blue print, whereas if the number off and date, &c., be written on the tracing itself, this will have to be altered or obliterated. The forging drawing dimensions should be the actual finished bright dimensions of the job, and this fact should be plainly stated on the tracing itself. Some firms also put the allowance to be made for machining (usually $\frac{1}{8}$ in. all over), but this is not necessary, for the forgeman, in his own interest, will take care to put on plenty of stuff, and usually a great deal too much. When the blue print is finished, it is handed to the general office to send away to the forge along with the order, and a copy may with advantage be also sent to the storekeeper for identifying the forgings when they come in. The forgeman should also be instructed, when delivering the forgings, to paint the given working number on each forging, so as to further assist the storekeeper in recognising them.

The next form to be filled in by the draughtsman is a complete list of all the bolts, studs, and nuts to be used on the job. This form is ruled as follows :—

Form F.

BROWN AND CO., Engineers, Tutbury.
List of Bolts, Studs, and Nuts required for
Order No..... Working No.....

No. required.	Description.	W.N.	Thread.	Diam.	Length.	Thickness.	Ordered	Received

This is to enable the storekeeper to make a collection of all that are required, and to put them by in one of a number of partitioned drawers specially set apart for the purpose. He hands these out to the fitter as they are required. As he puts away each set he ticks it off in the corresponding "Received" column, draws a line through the "Ordered" column, and writes out a slip of paper on which is written what the bolts, &c., are for, and puts the slip in the drawer along with the bolts. Any that he has not got in stock he either requisitions from the office—and it is usually far cheaper to buy ordinary sizes of studs, bolts, and nuts from specialists than to make them oneself, although, if really well-made ones are required, it is difficult to obtain a satisfactory article without making them oneself—or in the case of special sizes he writes out a list or makes sketches of what he requires, adding the working number, on a piece of paper, which he gives to the foreman turner, who proceeds to make them. This process ensures that there will be none of that expensive waiting for such trifles which is so common in most small shops.

The next and last form (G) to be filled up is a list of sundries, such as drain cocks, indicator cocks, lubricating pipe, and boxes, and similar things which are so often left until the last moment. These things, again, are usually very much cheaper to buy than to make. This form is ruled as follows:—

Form G.

BROWN AND Co., Engineers, Tutbury.

List of Sundries.

Order No..... Working No.....

Required.....

No. requir'd	Nature of apparatus.	For	To fit drawing No.	Ordered	From	Receiv'd	Remarks.

It has been before remarked that the draughtsman must, before proceeding with the drawings, be provided with either all the fittings themselves, or with drawings of them. (And it may here be remarked that it is very irritating to a customer to receive a job which is but scantily provided with proper fittings. It is far better to charge a pound or two more, and provide everything that can possibly be required—indicator cocks, drain pipes, and so on.) If the shop is slack, it may be advisable to make the fittings at home, so as to keep the men employed as far as possible. On the other hand, if the shop is extremely busy, and the job in a hurry, it may be decided to order such things as the crank shafts ready finished. In that case they would appear on the list of special apparatus, on Form G.

If it is decided to make any of this special apparatus in

the works, the castings and forgings for it appear in the other lists, and they are not entered in this list.

All these forms when finished are pinned together, and sent in to the general office. With Forms A and F the general office has nothing to do. From B, C, D, E, and G they write out formal orders to the firms from whom the respective articles are to be procured. These orders should give the number of each pattern as found from Form B, and should contain instructions that the *working number* is to be painted on each casting or forging before delivery, otherwise the storekeeper will not be able to recognise them. The general office also fill in columns 5 and 6, in Forms C, D, E, and G.

When all the sheets are as completely filled in as possible by the drawing office and the general office, and all the articles referred to in them are ordered by the latter, they are sent in to the storekeeper, who hangs them up in order on a row of nails in the stores, so that any one of the sets referring to any of the orders in the shop can be taken down when required without disturbing the others. How he uses them we shall see when dealing with the stores. Form B, however, is sent into the pattern shop.

From this form the pattern-maker foreman can see precisely what he has to do in order to get all the patterns ready to go to the foundry. As each pattern is ready it is stamped with its proper number, if this is not already done, and ticked off on the list in the column headed "Completed," and put on one side, all the patterns for one order number being kept together. Unless the job is in a great hurry, it is a mistake to send the patterns away in dribblets, as omissions are more likely to be made, and patterns lost, than if they are all collected and sent away together; besides which the cost of sending them away piecemeal is much greater than if they are all sent at one time. When all are finished, the draughtsman and the foreman pattern maker together go over each one with the rule, and as it is measured over and found correct, the

Form B is initialled by the draughtsman in the corresponding space, and the form is then sent to the storekeeper.

Now, this will seem a complicated and elaborate system to those numerous employers who are accustomed to do things in the rough-and-ready methods of the time of James Watt—to work with half-finished drawings, that have been made for some other job, and who let the workmen or the foreman do two-thirds of the designing, and the latter all the ordering, just as he happens to remember. Employers of this type may be recommended to examine their balance-sheet, and compare their cost prices (if they know them) with the selling prices of a smart up-to-date firm.

Workshop drawings are most convenient to use when they are made much smaller than the usual imperial size. There is really no reason at all for the large size which it is customary to employ, and it is extremely inconvenient to handle a large drawing. The most convenient standard size is, for detail drawings, 15 in. by 10 in. General arrangements will, of course, be as much larger as may be required to show all the details and dimensions clearly. Only one article should be drawn on one sheet. If the latter plan is not adopted, it will often happen that three or four men will be wanting the drawing at the same time, which will cause a great waste of time. Some foremen think, however, that it facilitates the detection of errors if all the details are put on one sheet; but there ought to be no errors to detect if the drawing office is efficient.

The drawings sent in the shop must be worked to *exactly*. No departure of whatever kind, or however slight, is to be made from the drawing under any circumstances whatever, until the head draughtsman is informed, and his consent obtained. There are circumstances when a departure from the drawing is inevitable: such, for instance, as when a casting comes in with the flanges not correct, so that if the distance of a face from the centre line were made to the drawing size the flange would be too thin. This fact will be found out by the marker off when the casting first comes

in; so that if the drawing is to be kept to, it means that the casting is to be rejected. When a case like this occurs, the head draughtman's attention must be called to the fact immediately. If this will make any important alterations in bolt holes, or otherwise, it may be necessary to reject the casting. If, however, it is unimportant, the casting may be allowed to pass. But at anyrate the foreman must not take upon himself to depart from the drawing in any particular. Such a fact as this having been pointed out to the head draughtsman, and the casting having been passed by him, he takes a complete and accurately-described note of it, to be inserted in the Record Book, D VII. If, then, at any future time a question arises about this job, this fact will be known to the head draughtsman of that time. If any other departure from the drawing is desired by the foreman, he must not on any account make it until the head draughtsman has sanctioned it, and had all the drawings bearing on the point altered to suit. The alteration to the drawings must be a preliminary to that alteration being made in the works. Endless confusion will arise if this rule is not strictly observed. Similarly, when the foreman or a workman discovers any errors in the drawing, they must be rectified on *all* the drawings and photo prints, both works and office, before the job is proceeded with. When the job is finished and sent away, the order sheets are all sent again into the drawing office by the storekeeper. The head draughtsman then proceeds to make any entries that are required in the Drawing-office Pattern Book, D IV. (see page 26), deriving his information from sheets B, C, and D. Thus to the illustrative extract there given he would add, "Altered to 16/208 for W N 15,760," and to fill in from sheets C and D, the actual weights of the castings (which have been entered up by the storekeeper when the castings arrive), and also to write up the Record Book, D VII. When this has been done the sheets are stored away in the drawing office. This Record Book contains fullest possible particulars of the execution of each order as it goes away.

In the normal course of things this resolves itself merely into a copy of the order itself, and a list of the drawings which were used for the various parts. In many cases, however, there will be one or more special notes recording certain inevitable departures from the drawing, such as those instanced above.

The book is ruled as follows, and in many of its particulars is almost a copy of Sheet A :

Drawing-office Record Book D VII.

Date .....
Order No. .....
Working Nos. .....
Date of order.....
Date of delivery .....
Order. (Here is copied the order from the cyclostyled order sheets.)

Drawing Nos. .....
Test record.....

Remarks—

In concluding this part of the subject, it may be remarked that the head draughtsman, as all other heads of departments, should have absolute control of the drawing office. All orders from the manager to the drawing office should go through the head draughtsman, and the journeymen draughtsmen must look only to him for their orders. He is held entirely responsible for the accuracy of all drawings and the organisation of the drawing office. He is to blame if a drawing or a reference cannot be found, and as he checks all drawings that go into the works, he must be held responsible for their accuracy. He should insist on all drawings, except those in actual use, being put away in the books every night. If this is not done, a great litter of drawings will rapidly accumulate in the drawers, besides

which they quickly get dirty if they are left throwing about. No accumulation of work should be allowed. If things are done and entries made at the time the job is in hand, it will save many mistakes.

With regard to other work, every distinct job that is done in the shop, provided it is not too trivial, should have its own order number, and no casting or forging should be procured except by the method we have described through the head draughtsman. This may seem foolish and unnecessary to many people, but it is absolutely necessary if the costs are to be accurately kept. If exceptions are allowed in some cases, they will extend until the whole system is thrown out of gear.

It is well to have a written list of instructions posted up in the drawing office, specifying all the particulars which are to be marked on each class of drawing or tracing, the position of the title or number, and other particulars. If this is not done, no sort of uniformity will be possible, and if certain particulars are missing, it will usually cause trouble to those who are dependent on the drawing for their information. In addition, there ought to be definite rules observed as to maximum stresses allowed, and intensities of pressures on bearings, and similar matters. These important particulars should not be at the mercy of every ignorant draughtsman who is taken on. There should be one rule recognised for each case, which should also be posted up, and no departure from it should be allowed except on the express instructions of the head draughtsman, which departure should be noted in the index entry of the drawing and in the Record Book.

There is also a Test Book, D IX., kept, which we shall deal with later on.

CHAPTER IV.

THE STORES.

THE order having passed out of the hands of the drawing office, it has now to pass through the stores. A good storekeeper is positively invaluable in an engineering works. When a really good man is found, the manager should take great care not to lose him if it can possibly be avoided, for on his thoroughness and competence the efficiency of the organisation of the shop itself largely depends.

He must, above all things, be methodical, thorough, honest, and orderly. It is a great advantage if he is himself a trained mechanic. His duties are not at all difficult, but they need constant attention, and none of them can be neglected without causing loss to the firm and confusion in the shop. In many small firms the storekeeper and the timekeeper are one and the same man, but unless the firm is a very small one the duties of each post are quite enough for one man to perform. Besides, the storekeeper must never be away from the stores under any circumstances (except for half a minute or so, when it is unavoidable), and the timekeeper is obliged to be often away from the timehouse, so that if both duties are entrusted to one man it means that the stores will be often left unattended. Not only does this cause a good deal of annoyance in locking and unlocking the stores door, for there is often a lot of valuable stuff lying about in the stores, but it hinders and annoys a workman who comes to fetch a tool to find the door locked and no storekeeper to give him what he wants. He will in nine cases out of ten do nothing till the storekeeper returns, and as there is always somebody coming to the stores for something, an absence of even a quarter of an hour is a serious matter. Besides which, storekeeping and timekeeping are two totally distinct things which have nothing whatever to do with one another, and the question is, Does it save 30s. or £2 a week to keep the stores thoroughly efficient? It would

be a very small works indeed in which it did not save a great deal more than that, because, if the stores are properly kept, it means that there need be no waiting for a particular size of stud or bolt, or anything else that is wanted, no looking for lost tools nor drawings, no waiting for the jobbing smith to fettle tools, and no confusion or chaos of any kind. Instead of this, everything that a man requires to go straight on with his job is ready to his hand, and he has only himself to blame if he does not get it done quickly. In addition, it leaves the foremen quite free to devote all their attention to their men, and that is all a foreman ought to have to do. It is a very mistaken policy to give a foreman a lot of book-keeping to do.

Duties of Storekeeper.—In the first place, the storekeeper has to receive or despatch everything of whatever kind which goes into or out of the works, and keep a record of it. His books ought to contain a record of every ounce of stuff that passes the gates of the works, and also the door of the stores, either out or in.

To continue the discussion of the order we are considering, the storekeeper is now provided with a list of all the stuff he has to receive for that order. He will first be concerned with the sending away of the patterns. The patterns are supposed now to be all packed ready to be sent to the foundry. Each pattern, and each part of it, each corebox and strickle, is supposed to be stamped in several places before they leave the pattern shop with the pattern number and the name of the firm, and also have the working number painted on. The storekeeper must see that each is so stamped and painted before it goes into the cart, and if not, he must send for the pattern-maker foreman to come and do it. Then, taking the lists with which he is provided, he must go over the patterns to make sure they are all there. The pattern-maker foreman must see that all the coreboxes and strickles, &c., belonging to one pattern, are tied together, as the storekeeper cannot be expected to know what core-boxes, &c., to look for. If any patterns are sent away

incomplete, the foreman pattern-maker is to blame. If any whole pattern mentioned in the list is omitted, the storekeeper is to blame. If any pattern is omitted in the lists, the draughtsman is to blame. When he has checked over all the patterns with his list to make sure they are all there, he fetches out of the stores his Pattern Book, which we shall call S I. This book is ruled as follows :—

PATTERN BOOK, S I.

Date.	Description.	No of pattern.	Sent to	W. N.	Date returned.	Signature of carman.

In this book he makes a complete list of all the patterns sent, enumerating all the parts. If he knows nothing of pattern-making, he will, at first, be at a loss to know how to describe the various parts of a pattern; but if the firm makes a specialty, he will soon become accustomed to giving them their correct names; until he can do so the foreman pattern-maker must help him. When he has got his list complete, the carman signs for them, and the patterns go away. He then enters the date in the order sheets concerned—that is, on sheets C and D, column 4—hangs them up in their proper place, and waits for the castings to arrive.

Orders to Foundry and Forge.—The founders and forgemen receive their formal order from the office. Each order gives them the number of castings off each pattern, the pattern being referred to by its stamped number, and also the order contains instructions to the effect that each casting has to be delivered with the same number painted on as is *painted* (not stamped) on the pattern, and that the patterns are

to be returned with the castings. The corresponding instructions to the forgeman are that the working number given on the forge sketch must be painted on the forging. It also contains instructions to the effect that the delivery note must refer to the number of the office order form, and also the working number of the job, both of which are given on the order form. The preceding system again will seem to many a very elaborate procedure to observe when sending off patterns, but there is no more work in it than is absolutely necessary to prevent patterns being lost. Hundreds of pounds worth of patterns may easily be lost in a year, if any less accurate system be adopted, besides which, if it is not done, and done thoroughly, there is not the least use in keeping any record of patterns at all, for in a couple of years most of them will be lost or destroyed. If a founder knows that the firm to whom the patterns belong is not keeping a strict record of patterns sent out, he will be very lax about returning them, and very positive that he either has not received, or has returned, any pattern that may be lost. His own carman's signature, or the want of the storekeeper's on the counterfoil of the delivery note, is a convincing proof to the contrary.

Between the sending away of the patterns and forge sketches and the receipt of the goods, the storekeeper must make a collection of all the bolts, studs, nuts, oil pipes, cocks, lagging, and all other extras mentioned on the order sheets. All these are put away in compartments reserved for this particular order number.

Requisition Book, S II.—Anything that he has not got in stock he immediately proceeds to requisition in the Requisition Book, S II. In this book is entered everything that is at any time required to be bought from outside. Nobody in the works should have any authority to procure anything from outside, or in any way pledge the firm's credit, to however small an extent. The proper way to proceed when anything is required which the storekeeper

cannot supply is to fill in a requisition to the office, in the book S II. Of course, there may be trifling exceptions to this rule. For instance, when the office is closed, and the men are working overtime, and such things as, say, two or three candles are required immediately—the foreman pays for them himself, and gets the money from the cashier the next morning. In ordinary circumstances the Requisition Book is used. This book is ruled as follows :—

REQUISITION BOOK, S II.

Date.	Quantity.	Article required	W.N.	When required.	Requisitioned by	Approved by	Date received.
13, ix.,'97	1 cwt.	Candles	Stores	Urgent.	W.R.P.		
,,	120 ft.	½ in. oil pipe.	15,215	——	L.R.		

Nobody should be allowed to requisition anything except the storekeeper or one of the foremen. This requisition book is sent into the office every evening an hour or two before the office closes. The manager or someone in authority should immediately examine it carefully, and either accept or reject the requisition. In the former case, he at once puts his initials in the last column but one, and gives instructions to the clerk who has charge of the ordering to either order the goods by the same evening's post or to write asking for prices. If he rejects the requisition, he goes into the shop to see the foreman (it is always a mistake to send for the foreman out of the shop when it can possibly be avoided ; the foreman should never be called on to leave his men) or storekeeper, who has signed the requisition, and either talks it over with him or tells him that the requisition has been rejected, and telling him why. The foreman must never be

left uncertain whether or not he is going to have what he has asked for. If the requisition is finally rejected, it is crossed out by the manager, and the foreman or storekeeper is informed of it. Again, the practice of ordering twopennyworths is never to be commended. The stores should be kept lavishly supplied with everything that can possibly be wanted, provided always that the stuff, whatever it is, is not being wasted. Ordering twopennyworths when £2 worth is used in the course of a year certainly multiplies the cost and trouble of ordering by 240, and probably by ten times that. If a workman at 9d. an hour has to work an hour for want of something that costs sixpence, the firm loses 3d. on the deal; and they *do* lose it, although the loss does not appear in black and white on their books. If the man has to wait an hour because the sixpennyworth is not in the stores when it ought to be, the firm loses 9d., and the 9d. goes down to the working number of the job, so that the firm doesn't notice it, and congratulates itself on saving the interest on 6d. for a week or two. This sounds very absurd when put down in plain language, but it is what is actually done every day in many small firms, whose proprietors plume themselves on their economical management of the works. The workman doesn't object to playing about for an hour, however much he may sneer and joke about it among his mates. The foreman dare not say anything about it for fear of a row, and the 9d. is never missed, but an accumulation of ninepences are missed when the balance-sheet comes to be examined, and, of course, "foreign competition" gets the credit of it.

When the castings or forgings arrive, they are accompanied by a delivery note, on which is recorded the weight of each casting, the order numbers, and sundry other particulars. The storekeeper has to sign, acknowledging the receipt of the goods and patterns. Before doing so, he takes the weight of each casting or forging on either the large or the small weigh-bridge, and examines if they agree with the weight on the delivery note. He also goes carefully over the patterns, and

checks them against the list of the patterns sent away, which he has in his pattern book. Opposite each one which is returned he enters the date. If the weights of the castings agree with the weight on the delivery note, and the patterns returned also agree with those mentioned on the delivery note, he signs the note, keeping the counterfoil, and the carman goes away. Or if he has not time to weigh the castings just then, he signs, adding the words "Not examined," but he should before doing so always make sure that all the articles mentioned on the delivery note have been delivered. When he has time he brings the Inwards Book, S III., and copies the delivery note into it if the latter is accurate.

In the Inwards Book he enters every article which comes into the works. It is ruled as follows :—

INWARDS BOOK, S III.

Date.	Quantity or number.	Description.	From	For	Weight.			Remarks.
					Cwt.	qrs.	lbs.	
		Castings—						
27, x., '97	2	Cylinders, 7 × 6	Robinson	15,760	3	1	7	

There are two of these Inwards Books, both precisely alike. One of them is used on Mondays, Wednesdays, and Fridays, and the other on Tuesdays, Thursdays, and Saturdays. Each night after work is over he takes the book he has been using that day into the general office, and brings back the other one for use on the following day. This gives the costing clerk an opportunity to keep the entries up to date.

If the founder has followed his instructions, each of the castings will have the working number painted on, so that the storekeeper will have no difficulty in identifying them.

If any casting is without the working number, the storekeeper must paint it on himself. If any firm supplying castings or forgings is in the habit of neglecting to paint on this number, the general office should be informed of the fact by the storekeeper, and requested to notify the firm that the instructions on this subject must be attended to. The delivery note will tell him what number it is, and will assist him in identifying the castings. He must be careful to paint the number on a part of the casting where it will not be cut off when the machining comes to be done. If any casting has a number painted on where it will be cut off, he must paint another number on where it will not be cut off, or, in cases when this is impossible, every machineman who cuts the number off must stamp it on again before he parts with the casting or forging. This is imperative if the costs are to be accurately kept, and the foreman must see that it is always done. To rely on verbal communications as to working numbers leads to serious mistakes in the cost books.

The storekeeper must next fill in the receipt of the castings or forgings, with their weights, in the order sheets C, D, and E of the job.

All the castings belonging to one job should be delivered by the founder at one time. They are to be kept together throughout, if possible. They are all included in one separate order. The patterns are all sent away together, and the castings should all be delivered together. Of course, in some cases this is impossible; for instance, if it is a very big job, or if it is in a great hurry. In the latter case the founder should be instructed by the general office, on the advice of the foreman, as to the order in which the castings are to be put in hand and delivered. In the former case several foundries may be working on different parts of the same job, but in a normal case all the castings will be delivered together. When this is the case the storekeeper should go over his order sheets, and ascertain (1) if any castings have been omitted; (2) if any patterns have not

been returned. He should then at once advise the general office, who should write the founder the same night, asking for delivery or the return of the patterns (of which numbers and other particulars should be given), as the case may be. If the pattern is left throwing about the foundry for any length of time, it will probably be lost or damaged, if any damage is possible more than that which a moulder usually does to a pattern in the ordinary course of business.

To some people it may appear that waiting for all the castings and materials mentioned in the order sheets to be delivered before going on with the job will cause delay in getting it finished. It will be seen, however, on a closer examination, that this is not so, unless the order is either a "push job," which must at all costs be got out as early as possible, or a very big one. In the latter case, when the independent machining of the castings will occupy a long time, and when it will not be delayed by the absence of some other parts of the work, there is no objection to putting the independent machining in hand, or when work is very slack in the shop, so that there is a difficulty in keeping the men fully employed on other work without encroaching too much on stock work; then the foreman must do the best he can with what work he can get, provided always the work he puts in hand is not delayed by the want of anything not yet delivered. But in no case should any fitting whatever be started on until all the parts which the fitter will require are ready for him. It is simply flinging away money to disregard this rule. If the fitter cannot go straight on with the job to the finish, he will "nurse" it and waste time on it until he can. It is in the highest degree detrimental to the *morale* of both the man and the shop that the man should be compelled to refrain from working as hard as he can because he has not got the material to work on. A man is spoilt for a long time if he has a legitimate excuse for wasting his time, or if his doing so is ignored from any cause whatever. A man who has not enough to do is a positive infectious disease in a busy shop;

hence the importance of making sure that all the stuff is in the shop before starting on the job. In the long run there is no loss of time due to this apparent initial delay in starting. In fact, time is gained—that is to say, a busy shop managed on this principle will turn out a job in shorter time and at much less expense than the same shop would if every casting or forging were pecked at as soon as it arrives. It simply means that the men are devoting all their attention to getting previous orders finished, and that instead of fiddling about with a large *melée* of orders at one time, they are vigorously working at a smaller number. One thing at a time is as good a rule in an engineering works as it is everywhere else. To keep a small number of men busily employed is obviously a better system than having twice the number of half idle men. Any order carried out on this system will more than make up for any delay in starting on it that may occur due to waiting for all the material by the rapidity with which it can be carried through the later stages.

Storing Castings and Forgings.—Having seen that all the castings and forgings have their respective working numbers painted on, the storekeeper has next to sort the smaller ones into the compartments specially reserved for them. Every article belonging to the job, except what is being actually worked on in the shop or what is too big for the compartment, is kept there, and nothing else is put in. Nothing should be left about the works unless it is in charge of the man who is working on it. Of course a man may have several articles at his machine which are all alike, and which have to be machined all together, but he returns everything else to the stores. The advantages of this arrangement are enormous. Finished work is preserved from damage and from littering up the shop. It enables the foreman to see precisely how much work he has in the shop, and how any particular order is getting on. It saves the waste of his time in seeking for jobs about the shop, and enables him to see the best order in which to put work in

hand so as to avoid delay of any kind, and has many other advantages.

Work Book.—The storekeeper has a book called the Work Book, S IV., which is ruled as follows :—

WORK BOOK, S IV.

Date.	No. of articles.	Description.	No. and name of man.	W.N.	Time to be returned.	Time returned.	Remarks.

The entries in this book are made by the foreman every time he gives out a job. He estimates the time to be allowed from the time curves, to be shortly described, and enters the time at which the job ought to be finished in the sixth column. He also writes on the man's time sheet a full description of the job and the time at which it is given out. This must be done with indelible pencil, so as to prevent the man from making alterations. The time sheets will be discussed in a future chapter.

Workmen's Tools.—The storekeeper has under his control the whole of the tools used by the men which are the property of the firm. Every tool, of whatever kind, must be deeply stamped with the name of the firm. If this is not done, the number of tools stolen may be enormous, if, as usual, there are two or three thieves in the place. It will always be considerable in any case, because most mechanics have a lathe and vice at home, and the tools they use are often largely "borrowed" from the firm they are working for. But it is always dangerous for a man to be in possession of tools stamped with the name of a firm. If the stamping

is not deep, it is easy to deface it by grinding or hammering it out. When a man is taken on he is supplied by the storekeeper with a lock-up box or drawer, containing a generous selection of the tools he will require. For a fitter these will consist of half a dozen chisels, a large hammer and a small one, and three or four files, and perhaps two or three spanners and scrapers, &c.; other tools, square, calipers, spirit levels, and the like he is expected to provide for himself. A turner will receive a couple of roughing tools, a right-hand and left-hand tool, a parting tool, a couple of boring tools, and a screw-cutting tool, and any spanners, &c., necessary for the special machine he is working on. Every man must also be provided with time checks and a time board for clipping his time sheet on. Similarly for any other machine-men. The storekeeper keeps a special book called the Workmen's Tool Book, S V., in which he makes a list of every tool supplied to every man, entered in detail under that man's name. The book is ruled as follows:

WORKMEN'S TOOL BOOK, S V.

Name, John Jones. *No. of Check*, 78. *Job*, Fitter.

Date.	Tool.	Signature of man.	Date returned to stores.	Remarks.

When a man gets an order for, say, a new file from the foreman, he must return an old file in its place, otherwise it is entered up to him as a new tool, for which he must account when he leaves. If he breaks one of his chisels, he takes it to the stores and receives a fettled one in place of it. Similarly with a turning tool. On no account must the men be allowed to go to the jobbing smith or tool smith to

get their own tools fettled, except on the express instructions of the foreman. If this is allowed, there will be continually found men skulking in the smithy, wasting their own and the smith's time. There are other special tools required occasionally, such as long chisels or peculiarly-shaped cutters for machines, which workmen may borrow, and which are entered up to them, just as taps and reamers are. These are not entered up in the workmen's tool book. To secure high economy and efficiency, a firm must be quite liberal with their tools, and quite ready to lay out money on any labour-saving device which will pay for itself in wages saved, but not otherwise. This piece of elementary common sense is largely ignored in this country. But every tool issued from the stores must be entered up and accounted for. Such things as files should go to working expenses account. It is absurd to charge them to particular jobs. A man may require a new file on a job for five minutes, and the rest of the life of the file may be spent on other work. It is obviously unfair to charge the file to the job for which it is issued in the first place. When a man leaves the firm's employment he must return to the stores all the tools entered against his name. He receives a receipt signed by the storekeeper when he has done this, and this receipt must be presented to the cashier before the man's wages are paid in full. If he has lost any tools, a corresponding deduction is made from his wages. There is no injustice to a man in this. If he takes the same care of the firm's tools as he does of his own spirit level, calipers, &c., he will not in general lose them. If he does lose them through his own carelessness, he cannot expect the firm to pay for them, any more than he can expect the firm to pay for any of his own calipers he may lose. If the tools are in this way regarded as the property of the men while they work for the firm, many mechanics would refrain from appropriating them, who would do so without hesitation if the rightful user of them was not held responsible. When the storekeeper has collected a sufficient number of chisels or other tools which

require fettling, he counts them, and books them to the smith in the Smithy Book, S VI., which is ruled thus :—

SMITHY BOOK, S VI.

Date.	No.	Description.	Name of smith.	No.	Date returned.	Remarks.
Nov., '97.						
20th	27	Chisels	Evers	79		
,, ...	18	Rough turning tools	,, ...	,,		

The smith fettles them, and returns them in a batch to the stores. The storekeeper with them sends an order to the smith, stating the number of tools sent, and any remarks or instructions that may be called for. The storekeeper has a box in which he keeps all "jiggered" files. When it gets full he weighs it, and sends the contents to the file cutter to be re-cut. No files are allowed to be made into scrapers or other tools. The storekeeper has a stock of steel scrapers, which he gives out for this purpose when required, entering them up to the men along with their other tools. For any new tool he gives out he must get a foreman's order. A very ample stock of tools of all kinds must be kept. A man who wants any tool, of any conceivable kind, should be able to get it at once from the stores. In such things as drills, two or three of every size and kind of drills should be kept, together with sockets, so that any drill will fit any machine in the shop. Many firms are very chary about supplying the tools with twist drills on account of the expense, whereas a well-made large twist drill is one of the best investments a firm can make, and will almost pay for itself in boring half a dozen holes. In a firm of any considerable size, one or two tool fitters and grinders may be employed with profit. In some American firms no workman is even allowed to go to

the grindstone himself. All the grinding is done by special men, who do nothing else but grind tools left in the stores, on special grinding machines made for particular purposes, and who are therefore ten times more expert than the ordinary fitter or turner. In this case, of course, a man whose tool wants grinding takes it to the stores, and changes it for a ready-ground one. The grindstone is a favourite conversational resort in most works. If a man wants a special tool for any purpose, the storekeeper may allow him to look over the stock of tools in the stores to select one suitable for his purpose, and if there is not one there, one is made at once by the smith, who puts aside all stock work for the purpose. If this plan of distributing tools is adopted, the firm will not need one-quarter of the tools which will be necessary if each man has a private stock of his own. The number of tools which an old hand will collect for his own private use in course of time is enormous. In a carelessly managed shop, where this want of system exists, when a man is known to be leaving he either distributes his tools among his private and particular friends, or, if he omits this formality, the moment he is out of the shop his cupboard is raided, and broken open if necessary, and all his tools taken to other machines, and when a new man is put on the machine a fresh set of tools has to be made for him, although there may be already in the shop ten times as many as are necessary. If workmen were ready to lend tools to one another, this system would not be so imperatively necessary, although still eminently desirable. But the men who have the largest collections will often guard them as jealously and selfishly as if they were made of gold, and will refuse even to lend any of their superfluous stock, for fear they will not see them again. In particular, when a non-unionist is taken on at a unionist shop, not a man will usually lend him a tool of any kind, whereas a properly-arranged stores will render him independent of any animus of this kind.

General Tools.—With regard to general tools, such as taps, reamers, wrenches, jigs, templates, &c., they are all kept in

appropriate compartments in the stores. The storekeeper keeps a book containing a list of everything of the kind in his possession. This is called the Shop Tool Book, S VII. It is ruled as follows :—

SHOP TOOL BOOK, S VII.

Date received.	No.	Taps. Description.	Received from.	Stored.	Date replaced.	Remarks.
21, vi., '97	3	$\frac{5}{8}$ taps (set)	Shop	D 17, 16		
25, vi., '97	3	$1\frac{1}{4}$ taps (set)	Whit.	D 17, 8		

In this the storekeeper enters every tool as he gets it, under the appropriate heading. When any tool is done with he enters the date and crosses out the whole entry, but in such a way as to leave it legible. He or anyone else can thus see at a glance what tools he has in stock, and how long they last, and where they are stored. Thus, the $\frac{5}{8}$ taps are kept in drawer 17, compartment 16. When he lends any of these to a man he enters it in the Tool Book, S VIII., which is ruled as follows :—

TOOL BOOK, S VIII.

Date.	Description.	Lent to.	No.	Returned to stores.	Remarks.
17, xi., '97	Three $\frac{3}{4}$ taps and wrench	King	27		
,,	3 in. steam template....	Palmer	43		

So that if any tool is wanted he can say at once where it is. Every workman is responsible for any tools lent to him until they are again returned to the stores. If he lends the tool to another workman, he does so on his own responsibility, and is held liable if it is lost. Each line in the "Returned to stores" column must be filled in, and if any space is blank for a day or two, the storekeeper or his labourer should go to the man to inquire after the tool, and if the man has lost it, the amount must be deducted from his wages.

But tools are never lost if this arrangement is made. If a tap is broken, the storekeeper should be able to replace it at once from stock. Two sets or more, according to the size of the shop, of each size of taps should be in use at the same time, and several sets kept in hand. It is not usual to make a man pay for a tap he breaks. A reprimand from the foreman is usually the only result of it as far as the man himself is concerned. When the stock of any size of tap is running low, the storekeeper either requisitions some more from the office, or, if such things are made in the works, gives the foreman turner an order for some, either through the manager or directly. In theory the order for such things should come from the office on the storekeeper's requisition, but if it is the custom to make the taps in the works, it is perhaps unnecessary to trouble the office.

Drawings are treated exactly as the tools already described. When a job is definitely put in hand the storekeeper takes the bundle of drawings sent in from the drawing office, and sorts them into numbered compartments, each compartment bearing the number of the book from which the drawing is taken. Thus, drawing 14/208 would be put in compartment 14, the drawings in that compartment being arranged in numerical order, and the number of the drawing being in such a position that it projects outside the rack, so that the storekeeper can see it without pulling all the drawings out. When a man comes in for, say, the 7 by 6 bed-plate drawing, the storekeeper can at once tell from the order

sheets what is the number of the drawing, and in consequence where it is to be found. He keeps a Drawing Book, S IX., similar to book S VIII., which is ruled as follows :—

DRAWING BOOK, S IX.

Date.	Description of drawing.	No. of drawing.	Lent to	No.	Return'd to stores.	Remarks.
17, xi., '97.	7 × 6 bed plate.	14/208	Ingham	178		

He watches these drawings just as he watches the other tools, and if any one of them is not returned within a reasonable time, he goes to inquire after it from the man to whom he has lent it. He has usually two copies of each drawing, as photo prints are so cheaply made that it is usually economical to have more than one ; especially is this the case where more than one part of the engine or other machine is given on one drawing, a practice which is by no means to be encouraged. When a job is finished, and before he sends the order sheets back into the drawing office, he has to collect all the drawings from the rack, and store them in their proper place in a large drawing case, so that he can at once find any drawing which the drawing office refers to on any future order sheet, and transfer it to the rack, which latter is, of course, kept for drawings of work going on in the shop.

Stores Labourer.—There is a labourer specially attached to the stores, who has to hand out dirty stuff, run errands, &c. He has to see that all finished work is kept well smeared with anti-rust grease, and to go in search of tools, &c., which have not been returned. When there is nothing for him to

do in the stores he can be employed on other work, but should always be at hand when required.

The next book kept by the storekeeper is the Outwards Book, S X., which, like the Inwards Book, is kept in two parts for use on alternate days, the part not in use being in the office.* Everything that goes out of the shop and all the stock that goes out of the stores is entered in the Outwards Book. This remark applies to such things as patterns sent to the foundry, these not being entered in detail, as in S I. The analysing of the various entries is done in the office. Nothing in the way of book-keeping should be done in the stores that can possibly be done in the office.

The Outwards Book, S X., is ruled as follows :—

OUTWARDS BOOK, S X.

Date.	Quantity.	Description.	To	Marks.	Size.	W.N.	Weight. c. q. lb	Remarks.
17/10/97	1	Case containing 1 7×6 engine complete, 1 stop valve, 3 drain cocks, 2 indicator cocks, 6 lubricating boxes, 6 turned coupling bolts, 7 oil pipes, 4 foundation bolts.	L.N.W. Ry.Co.'s van.	K. & Co. S.K. Valparaiso.	7′ 6″ × 4′ 0″ × 5 6″	15,760	25 3 4	

The storekeeper superintends the packing of all cases to go away. The special instructions as to packing, marks, &c.,

* The keeping of the Outwards and Inwards Books in two parts may be avoided if desired by keeping a carbon paper copy of every page of entries, which is sent into the office every night.

are sent in on a special form from the office. The storekeeper keeps a list of all the articles and separate parts put into the case, which he enters in the Outwards Book, as shown. It may sometimes be necessary for the head draughtsman to see that all the parts shown on the general arrangement—that is, everything included in the order—is packed in the case. But if the general arrangement is complete, and the storekeeper reliable and intelligent, this will not generally be necessary. At anyrate, some reliable and responsible person must be appointed to check over the contents of the case with the general arrangement, to make sure that the consignment contains everything included in the order.

Iron and Steel.—The storekeeper has also charge of all the stock of iron and steel used by the smiths. It is not, of course, stocked in the stores, but none of it must be used without passing through the storekeeper's hands. He has a special book—which is really part of the Outwards Book, but which it is convenient to keep separate—called the Iron Book, S XI., in which the iron and steel used is accounted for. It may be entered in the Outwards Book, but the difficulty is, that when a smith wants some iron for some purpose a much larger piece has to be given to him, from which he cuts off what he wants and returns the rest. All the three weights ought to be entered, but the ruling of the Outwards Book is not convenient for the purpose. The ruling of the Iron Book is as follows :—

Iron Book, S XI.

Date.	Quantity.			Description.	Name of man	For.	Weight of finished article.			Weight returned.			Remarks.
17/12/97	..	2	20	1½ in. round iron.	Evers	Counter-shaft for 121 lathe.	..	..	23	..	1	25	

This book, if kept separate, is in two parts, like the rest of the Outwards Book. The last book kept by the storekeeper is the Heavy Stock Book, S XII. In this he keeps a list of all the heavy work that he puts to stock. Thus, when half a dozen connecting rods are made to a stock order, they are sent, when finished, to the stores, and the storekeeper enters them up as shown below :—

HEAVY STOCK BOOK, S XII.

Date.	Quantity or number.	Description.	Where stored.	From.	D. No	Date used.	For.	Remarks.
25/11/97	6	9 × 8 connecting rods.	256	Shop.	14/53	(1)		
						(2)		
						(3)		
						(4)		
						(5)		
						(6)		

Small things, such as studs or bolts, are not entered in this book ; but anything of any considerable size which is ordered for stock, and not for any special order number, is entered in it. Things which are ordered for an order number are placed when they arrive in the compartments specially set aside for those numbers until wanted in the shop, and they are booked in the Inwards Book and the order sheets, but not in the Stock Book, which is only for unappropriated stock. A copy of S XII. should be in the hands of the head draughtsman, who gets the book from the stores about once a week, and brings his own book up to date. In the Stock Book should be entered all the castings and more or less finished forgings which are usually left throwing about in odd corners of the works, nominally

waiting until there is some opportunity for bringing them in. It is far better to put such things on the scrap heap at once, unless there is some definite prospect of utilising them within a reasonable time. At anyrate, if they are kept with this object in view, they must be entered in the heavy Stock Book, so that the drawing office may watch for an opportunity of working into their designs what there is in stock. Many engineers will think that there is far too much bookkeeping in this scheme. The author is convinced, however, that none of it can be dispensed with if the stores are to be efficient, and he knows from experience that one man can manage the whole of it in a works employing from 100 to 150 hands. If it is found to be too much for one man, it will pay to put two on the work.

In an efficiently-managed stores things must be so arranged and the books so kept that an intelligent stranger coming into the place for the first time should be able to tell from the books exactly what is and what is not in the stores; and not only so, but he should be able to lay his hands on it in a moment with absolute certainty, and without having to search through a heap of other things. There must be a definite place for everything, and everything must be kept in its place, and the books must show where that place is. Of course, the making of a stores where a system of this kind is possible will cost money; but it is the best possible way of laying out money to have the stores in good order.

CHAPTER V.

The Timehouse.

The duties of the timekeeper are primarily to book the time at which every man goes into or out of the works. He must, above all things, be punctual and strict in the performance of his duties, without being in the least afraid of the men. The best timekeepers are usually retired soldiers, who are accustomed to strict discipline. It is very desirable that the timekeeper should be civil and reasonable, but if a man is a strict disciplinarian, he is not usually noted for his civility. It is by no means to the advantage of a shop that the timekeeper should unnecessarily aggravate the men by slamming the door in their faces, insulting them when they remonstrate, and performing other necessary duties in the offensive manner which timekeepers usually adopt. A man can be very strict without being uncivil, and it is always well for him to administer the rules with discretion. It is extremely annoying to the workman to see the timekeeper slam the door in his face or change the box before his very eyes, especially when he is quite convinced (as, of course, he usually is) that he has a minute or two to spare. This proceeding is usually followed by an argument on the question with the timekeeper, of which the latter invariably gets the best, and the workman goes into the shop with the fixed determination to make the firm pay for the dispute, and he can easily do so with a very high rate of interest without being found out. It is always bad to let a man start work with a grievance, for he never works well when he has one. By far the best plan is to adopt one or other of the many automatic time-registering machines on the market, by which the door is shut by an automatic mechanism controlled by a standard clock, which latter is always kept, say, two minutes behind time, and the timekeeper must always be extremely careful to regulate the clock exactly by standard time, so that the aggravating

feeling of having had a run for nothing is reduced to a minimum, and the exasperation of being, in addition, insulted by the timekeeper is entirely avoided. It is difficult to say exactly what is the best rule to make with regard to the times of admission. The usual practice in the country is to admit up to 6-5 in the "first box," up to 6-15 in the second, and up to 6-30 in the third and last box, after which time nobody can start till breakfast time, except for some very good reason, and with the express permission of the foreman. The time after breakfast is 8-30 sharp, and 1-30 or 2 p.m. (as the case may be) after dinner. A note should be taken of the reason for admitting any man after these times, and the manager should insist on this being done, as exceptions in this respect are very apt to become the rule. In such cases the timekeeper will refuse to admit men who are habitually late. The difficulty is to find a timekeeper with sufficient firmness to administer the rules strictly, and yet with enough judgment to do it with discretion. In London shops it is almost impossible to maintain strict rules, as many men have a great distance to come.

The usual method of taking the time is for each man to be provided with four time checks, each bearing his number stamped on. They are hung up on a hook bearing the same number, for him to take off when he comes at six o'clock. He puts one of these into the slot every time he enters the works. The timekeeper changes the box under the slot at the stated times, or this is done automatically, and the timekeeper notes on the time sheet the checks found in the boxes at the respective times. The timekeeper must be at hand to see that no man puts in more than one check, otherwise the door is opened for extensive fraud by "personation." The slot should be too narrow to admit more than one check at a time, otherwise a man can slip in two, without the possibility of detection.

There are other automatic devices on the market for checking the time at which men arrive. In one each man as he arrives prints his own number on a moving strip of

paper, which is moved by the clock. Whatever the method, the timekeeper enters the time in a book ruled as follows:—

TIME BOOK, T I.

Week ending Thursday.....

No.	Name.	Time of arrival.						Remarks.	Time of departure.						Remarks.
		Fri.	Sat.	Mon.	Tues.	Wed.	Thur.		Fri.	Sat.	Mon.	Tues.	Wed.	Thur.	

Each man as he leaves at night puts his time sheet (to be shortly described) into a letter box at the door, which is opened by the timekeeper a few minutes before the bell rings. The time of departure is filled in by the timekeeper from the time sheets found in the box. If he finds a man's time sheet missing, he makes no entry until he sees the foreman, and the man's wages for that day are stopped by the office, pending an explanation from the man. The same thing is done if any time sheet is found unsigned. The timekeeper has also to check over the tickets put in after breakfast and dinner with the list of men supposed to be at work. If he finds one missing, he closes the man's time account for the day, after inquiry from the foreman, noting the reason for absence (if any) in the "Remarks" column, and making sure that the man has given in his time sheet, otherwise his wages are stopped for the time that he has worked.

This book is sent into the office every Thursday evening, and the wages are calculated up to then, two days' wages being kept in hand. The timekeeper may calculate the total time made each week by every man, but this is usually done in the office. Another book, the Time Record Book, T IL, is kept by the timekeeper, containing a résumé of the time kept by each man. This book is entered up by the timekeeper at the end of each week. It is ruled as shown on page 82.

Each man's time is entered each week in three columns, as shown. The first column contains the number of whole days lost by the man, the second the number of quarters or "breakfast times" lost during the week, and the third the total hours lost by being behind time in a morning. This column also gives by shifting the decimal point the mean minutes late per day. Thus, if a man has lost altogether in this way 1·25 hours, he has been on the average 12·5 minutes late each morning.

The timekeeper should also calculate each week the average time lost per man per week over the whole shop. The result of this calculation is entered at the foot of each week's time. The object of the book is to enable the manager

(who should examine all time books every week) to see at a glance every man's time record for a long period without

TIME RECORD BOOK, T II.

No.	Name.	WEEK ENDING Nov. 4.		Nov. 11.		Nov. 18.		Nov. 25.			
21	Ongley.....	0	1	0	1	0·5	1	0·7	1	1	8·5
22	Wilks	1	1	0·5	2	0·7	0	1·5	0	0	1·7

turning over a lot of pages, and whether the shop as a whole is maintaining a good standard of time, or whether it is

deteriorating in this respect. Indirectly it is also a gauge of the amount of influence exercised by the foreman in the shop. A good foreman can always maintain a good standard of time in a shop without sacking all those who are remiss.

In calculating this average it is a little difficult to know what figures to reject without making the calculation unreliable. For instance, if any man has been ill for three or four days during any particular week, or has been away on a holiday by permission, it is obviously unfair to let that stand against the credit of the shop, because it will have a serious effect on the average if it is included. On the other hand, if it is omitted, where is the process of omitting inconvenient figures to stop? The best rule to observe is that the time of any man who has permission to stay away, or any man who is genuinely unwell, may be excluded, but a note of all excluded figures should be kept side by side with the result. The best plan is to underline with red ink all figures not reckoned in the average, and to make a marginal note of the reason.

It should be clearly understood that if a man is away through illness, he must immediately send word of it to the foreman, otherwise his job is not guaranteed to him on his return. The timekeeper should go occasionally, if possible, to see suspicious cases. Of course, the usual cause of illness is that the man has been drunk the night before. This should not be regarded as a genuine case of illness, and should be treated as an absence without permission in cases where it is known to be the real cause. Of course, nothing is easier for a man or apprentice who wants a holiday than to say he is "ill," but it will tend to make these cases as infrequent as possible if it is known in the shop that every time record is carefully watched, and that invalids are regarded as undesirable workmen.

Every foreman should see the Time Book every day, and should make and initial any notes as to cause of absence in the column headed "Remarks." In this column he must also enter the reason for admitting any man after hours Unless some definite rules are strictly observed, the time-

will always become lax. This is a very undesirable state of things, because if the men are allowed to be slack about their time, they will infallibly be slack about their work. Nothing is worse than to give the men the impression that the shop is "slack" in regard to matters of discipline. They do not value their jobs nearly so much as they do in a first-class place, where every point is watched; neither have they as much interest in their work, unless merit secures recognition. No man will work his best unless he sees that his doing so is observed and appreciated.

It is one of the most difficult problems with which a foreman has to deal to know what to do in regard to lost time. Every foreman knows that some of the very best workmen are habitual drunkards, and the very worst timekeepers. This, perhaps, is partly due to the fact that they know that they are too good to be lightly got rid of, which will, of course, make them careless about observing rules which inferior men dare not break. At anyrate, whatever the explanation, the lamentable fact remains that many of the best workmen are the hardest drinkers, and therefore, generally (but not always), the worst timekeepers. Many men who are habitually drunk are never known to lose a minute. These, however, are the exceptions. As a general rule, drinkers are bad timekeepers. It appears to be as easy for some men to go on year after year without losing a single minute, as it is for others to lie in bed till breakfast time twice or three times a week. In regard to time, as in everything else, the only way is to make a definite rule and to stick to it, whatever the cost. But even when the rule is made it is often very hard to abide by it in all cases. It is very trying, indeed, when the loser of time is a capable and valuable man. A man will sometimes work with tremendous energy while he is in the shop, and do twice as much work as other men, and of better quality. The foreman knows that he can quite safely leave him to himself for whole days together, and be quite sure that he will work just as hard and as well when left to himself as he will when somebody

is standing over him. Yet he will be extremely unreliable as to time. It is no use talking to him ; it does not have the slightest effect except to make him worse. If he is left to do as he likes, it will be impossible to keep other men up to time. The only other alternative is to lose the best man in the place, whom it may be difficult to replace.

However, the foreman must decide one way or the other. In the author's opinion it is best to dispense with the man, but it is a very difficult decision to make. Many a foreman has kept a man year after year, and put up with all manner of eccentricities without being able to screw up his courage to the sacking point, because he thought he could never replace him if he lost him. When, after some particularly outrageous piece of impudence, the man has been "pushed," a better one has turned up in a week. It is really a mistake to suppose that there is only one man in the world can do a particular job. Generally speaking, more than one quarter per week is considered bad time, and men losing more than this persistently should be dismissed after ample warning. It is a strange trait in human nature that such warnings seldom produce any lasting effect even with men who are keenly anxious to keep their positions. A man will readily enough promise to mend his ways, and his time will show a slight improvement for a week or a fortnight. Then he will gradually fall away again, and he has to be reprimanded each time with greater severity. He eventually becomes accustomed to reproofs and threats, and either seems to think they mean nothing or he gets reckless. The only thing left is then to carry out the threat of sacking him. He will probably come back to the shop again after a week's holiday, and ask to be taken on once more with renewed promises of improvement. If the foreman does decide to give him another chance, he will in 99 cases out of 100 slide back into his old form after about a fortnight. It is rarely any use trying to reform a bad time-keeper. Bad timekeeping is an infectious disease with which only the very robust can come into contact without

being contaminated. Whatever regulations in regard to maximum lost time allowed per week is determined on, it should be well understood by the men and strictly adhered to. If the matter is put on an exact basis, there will not be much trouble in this respect.

The average time lost should be plotted by the timekeeper on a chart. Every morning after breakfast he calculates what is the total time lost that morning, and divides this by the number of men included in the average. He should then plot the time thus found on a chart consisting of a long strip of squared paper. This curve is very instructive as showing how various events influence the time kept by the shop as a whole. The absence of the man whose duty it is to remonstrate with bad timekeepers has always the effect of making the curve rise perceptibly. The approach and passing of a bank holiday is similarly easily recognised on the chart. Any kind of disturbance in the trade such as a threatened strike has a similar effect. A change of foreman would probably do the same, but the author has not had the opportunity of observing the last as he has the previous three.

Time Sheets.—The next duty of the timekeeper is to distribute the time sheets. There is in most works a curious and somewhat absurd laxity in the arrangements whereby the cost clerk has to ascertain the cost of an order executed by the firm. In one shop known to the author half sheets of note paper are distributed to the men in the shop on Saturday mornings, and they are required to write thereon the number of hours spent on each of the jobs on which they have been engaged during the week. Whether the theory of this convenient labour-saving method is that the men are supposed to keep notes of the time they spend each day on each job (a thing they never dream of doing), or to keep the same thing in their memories (which they make very little effort to do), the result is obvious. They put down the first thing that comes into their heads, and the only care that they take is that the hours shall add up to 54. These precious and

reliable documents are then given to the timekeeper who enters the time to the various order numbers, and it is from this accurate source that the manager has to draw his information for making future estimates! It is not too much to say that with such a method the resulting cost might easily be 500 per cent in error. How can a man be expected to remember on Saturday what he was doing on Tuesday or Wednesday? In many cases all he will remember of the earlier part of the week will be that sometime during the week he was perhaps chipping something all one afternoon and part of the next day; he then makes a rough estimate on that basis. More generally he remembers nothing whatsoever about it, and puts down the first numbers that occur to him.

Other firms supply boards which the men rub over with chalk every day, or every other day, and write thereon the time spent on the various working numbers, as far as they can remember. They do not mind much what they put down as long as it adds up to 9½ hours each day. These boards are thrown into a box as the men leave the place at night. The timekeeper copies such of these figures as are not obliterated by the rubbing, into a book which he gives to the costkeeper. Now this kind of thing might have been tolerated when engineering shops were paying 50 or 100 per cent dividend, but it is utterly absurd when applied to the close-cut dealings to which competition has reduced us in modern times. The proprietor must not only be able to tell accurately the exact cost to him of the whole job, but he must be able to ascertain the cost of any special part of the job, and the cost of any of the operations necessary to produce that part. Take the order we are considering. The books should show accurately not only the final cost of the pair of engines, and therefore the actual profit or loss that has been made on the job, but also what it will cost to renew, for instance, the piston rod, or to machine up the cylinder and valve face. The costs should be arranged in such detail that he can tell the cost of turning the connecting

rod, or of slotting it, or of any other operation about the whole engine. He is then in a position to quote to a nicety for any work that may be offered him in the future. It is also necessary for the foreman to know exactly how long any particular job ought to take a man to do, in order to be able to fill up the Work Book.

Of course, by long years of experience most foremen get a rough general idea as to the length of time required for any particular job, and where the work is of a class that the firm is unfamiliar with, this experience is perhaps the safest thing to rely on; but at the best it cannot be trusted to within 25 per cent. The foreman ought to have such books to refer to as will tell him to within a very small fraction which of two men may be expected to do any particular job most quickly. It is only in this way that he can compare with any certainty the relative values of the various workmen. In very few workshops is there any reliable method of doing this. The wages are determined according to the fancy of the foreman, and of necessity much injustice is often done.

The system now to be described was devised by the author, carried out under his supervision, and found to fulfil the requirements explained above quite satisfactorily.

Each man is provided with a time board on which to clip the time sheets. They are merely a piece of board with a paper clip tacked on, which nips the paper against the board, and provides a convenient ring for hanging up.

Every day a time sheet, ruled as shown on page 89, is given to each man as he enters the works.

He clips this on his board, and fills it in as far as possible, as soon as he gets into the shop. That is to say, he fills in his name and number, and the job he is on with, describing it in detail. The foreman must be instructed to insist on the sheets being kept up to time, and in such a state that the manager or anyone else who comes round can see exactly what the man is doing, and, if it is a job occupying not more than a single day, how long he has been at it.

The particulars shown on the form appended are all to be filled in. When a foreman gives a man a job, he must either

Time Sheet.

MESSRS. BROWN AND CO., Engineers, Tutbury.

Name, *Taylor.* No., *125.* *Monday, 27th August*, 1897.

W. N.	Fresh job, or continuation of old one.	No. of articles alike.	Full particulars of job.	No. of machine tool.	Time started on job to-day.	Time left off.	Finished or unfinished.	Total hours (not to be filled in).
2784	Continued. Second one.	2	Boring and facing 7 × 6 cylinders.	125	6-0	2-30	Finished.	
15,772	Started. First one.		Boring and facing 12 × 10 cylinders.	125	2-30	5-0	Unfinished.	

NOTE.—The times on this sheet must be filled in as soon as a job is received or finished. It must not be left till the end of the day. Every workman must have this sheet signed by the foreman before leaving work, and place it in the box provided for that purpose at the door. Failing this the day's wages will be stopped.

Checked by.....

Foreman.

fill in the entry on the sheet himself, or see that the man does so properly, and that the time he puts down is correct.

It is much better for the foreman to do it himself. He should make the entries with an indelible pencil, so that the man cannot make any alterations. The time board, with the sheet clipped on it, is hung up in front of the man's machine. The filling up of these sheets must not be postponed till the end of the day, or they will not be accurate. The author has watched the effect of departure from this rule in many cases, and has found that no time in the morning, entered by a man at 5 o'clock, can be relied on within two or three hours. The man puts his time sheet in a letter box provided for the purpose, each night on leaving work. The timekeeper arranges them in numerical order the following morning, and enters them up in the Time Sheet Book, T II., ruled as shown on page 91.

This is a condensed copy of the time sheets. The jobs must be accurately described in the book, and the time spent each day on each job must be entered. One page of this book is set apart for each man. All the papers of one day must be dealt with on the next day. No arrears should be allowed. When the sheets show that a man has finished a job, the timekeeper must write "finished" opposite the entries, and add up the total time spent on the job. The column headed "entered" is for the date of entry into the Piece Book, T III. The latter is ruled as shown on page 93.

This book shows the total time occupied in doing each job, classified under the various jobs, together with all particulars which have an effect on the time required to do them.

Three or four or more pages of this book (according to the number of entries that are likely to be required) are devoted to each of the separate jobs of which it is desired to have exact information. The column headed "size" is marked out into suitable divisions, representing the standard sizes made by the firm, well spaced, so as to allow of the interpolation of intermediate sizes when required. When sufficient entries have been made in this book, they should

be plotted on curves on squared paper whose abscissæ represent size in any convenient way, and whose ordinate

TIME SHEET BOOK, T II.

No...... *Name of Man*..... *Date*.....*to*.....

W. No.	No. of articles.	Job.	No. of machine.	Time brought forward.	Fri.	Sat	Mon.	Tues.	Wed.	Th.	Total.	Enter'd.

represent time occupied. The points marked will in almost every case be found to vary widely, so that the curve will

be a mean between them. The author has found that the points representing one man's performance usually lie on a fairly smooth curve.

The timekeeper will not usually have sufficient intelligence to plot the curves himself. The drawing office is the best place to do them. These curves when drawn are of the greatest possible value to the firm, enabling them to determine the time required for any size of article with the greatest exactness that the nature of the case permits, and also enabling the foreman to see at a glance the actual comparative value of the various men under him as far as quickness of work is concerned. If the points representing a man's performances on various jobs come consistently above the curves, it is at once obvious that he is not up to the standard. Another great advantage of this method is that if the men know that the time spent on every job they do is entered against them for the purpose of comparing their time with that of other men, it encourages the spirit of emulation so conspicuously lacking in English shops. Actual examples taken from the author's own experience will illustrate their value more than pages of letterpress could do. These will be shortly given. There is, however, in many cases a difficulty in deciding how to fix the scale of sizes for these curves. Take in illustration the boring of cylinders. We may have to plot on the curve the time taken to bore the following sizes of cylinders : $6 \times 10, 7 \times 6$, $8\frac{1}{2} \times 5$, $8\frac{1}{2} \times 7$, $8\frac{1}{2} \times 15$, 10×8, 10×12, and so on. The question is how these are to be plotted along the horizontal base. A little common sense will usually decide this question. Generally speaking, the time ought to vary with the total surface to be machined. This varies as the product of length and diameter, so that in this case the base is marked out into divisions representing this product. In the case quoted above, the following is the order in which the cylinders mentioned would come on the horizontal base—7×6 would be represented by 42, $8\frac{1}{2} \times 5$ by $42\frac{1}{2}$, 6×10, and so on. But even in this case it is not always possible to have a common

Piece Book, T III.

Class, **Connecting Rods.** *Job*, **Turning.**

Size.	W. N.	Name of man.	No. of mac'ne.	Date finish'd.	No. of articles.	D. No.	Time on each.	Rate of wages.	Cost.	Remarks.
5 × 5										
7 × 6										
9 × 8										
10 × 10										

sense basis without a great deal of trouble, because the amount of work necessary to do a job on a piece of machinery is not always a function of the size alone, so that in many cases the curves would not be of any use. Still there are a great many curves that are extremely useful, and if the work done in the shop is of such a character as to lend itself to the method, it is very advisable to draw them. It will be abundantly clear that if any exact system of this kind is to be satisfactorily worked, the greatest possible care must be devoted to ensuring that the time sheets are filled up, not only accurately, but also in much detail, for the whole of the information is derived from them. More than this, the working of the shop must be in conformity with the system. We do not, of course, advocate that the methods of the workshop should be determined by the requirements of timekeeping; but it so happens that a systematic way of managing the shop is not only necessary for purposes of accurate timekeeping, but also in order to secure economy in the shop itself.

Filling in the Time Sheets.—Every man must, without fail, put his time sheet, duly signed by the foreman, in the box when he leaves work. If he omits to do so on any day, his wages for that day should be automatically stopped, and he should be compelled to go round to the cashier, in the office, in order to get them. Men have a particular dislike to doing this. The necessity for strict observance of this regulation arises from the fact that it is extremely inconvenient to the timekeeper to get the various days' papers mixed up. The timekeeper must deal with each day's papers not later than the following day, because if a question arises about any of them it can easily be settled while the matter is fresh in everybody's memory, whereas if a day or two is allowed to elapse some mistake may easily arise in the books by reason of some of the circumstances being forgotten.

The men should simply be required (or better still, the foreman) to enter the time of starting the jobs and the time

of finishing. If a man has a number of articles, all alike, to do, he must enter the time at which he finishes each one, and if any of them have to be rejected for any reason, this fact must be stated on the time sheet. The total time spent is calculated by the timekeeper because he will do it much more easily and rapidly than the men, and because it is not advisable to make the system adopted more laborious than necessary to the latter. If the men have to fill in this column it is found that they make mistakes in calculating and often "cook" the figures in order to make them agree. About half an hour to an hour before work is over for the day, the foreman goes round to each of his men and carefully reads all the sheets in turn and makes sure that they are all properly filled up, correcting any inaccuracies, making any notes on them that are necessary, and then signs them. This duty is by no means a sinecure, and if it is not carefully and thoroughly performed it is quite impossible to carry out the system at all. The necessity for this great care will be apparent by considering one or two instances. Suppose that a foreman has given a man four connecting rods to be slotted round the eye, and that the man has filled up his sheet as follows :—

17,650	Continued	4	Slotting connecting rods	78	6-30	5-0	Finished.

Now, there are two distinct slotting operations in a connecting rod of the type we are considering. One of these takes about twice as long as the other. It is not possible for the timekeeper to know which of these operations is referred to without asking the man or the foreman. This involves a waste of his time, and is also particularly annoying to him. When dealing with the distribution of

work we shall point out that it is necessary that all pieces of work of the same kind shall be done on the same general plan, so that the timekeeper will always know the meaning of the various entries on the sheets.

Secondly, suppose that a foreman, being rather short of work in the shop, has another slotter standing with nothing to do, and take one of the rods from the first man to keep the other man going. Now, the first man has already entered on his sheet that he is on with four rods. If then, on going to another job after three rods are finished, he enters "Finished" in the sixth column, the timekeeper will enter him in his books as having finished four rods, when he has in fact only done three. Or again, suppose a man has four cylinders to bore, and say two of them turn out wasters. If this is not notified on the sheet the man will be credited with having finished four of them, when, in fact, he has only finished two. The time spent on the wasters will be deducted by the timekeeper if the time sheet supplies him with the requisite information. When a dishonest man comes to understand the system of entry he will often make false entries on his sheet with the deliberate object of securing credit that he does not deserve. It is things of this kind that the foreman must be continually on his guard against. Unless he can be induced to take up the system thoroughly it is no use attempting to carry it out at all.

It is, of course, impossible that every individual job in the whole process of manufacture should be entered up in this way in the piece book. There are a lot of little things to be done that can never be dealt with separately; but the better a works is organised, the fewer will be the jobs that have to be lumped together as "fitting." In a well-appointed works such things as connecting-rod bolts, screws, studs, &c., are done in quantities, say 100 at a time. These can then be entered up in the ordinary way.

One of the piece books is devoted to miscellaneous turning, slotting, planing, shaping, &c., &c., and any well-defined job that cannot well be classified in the ordinary books can then

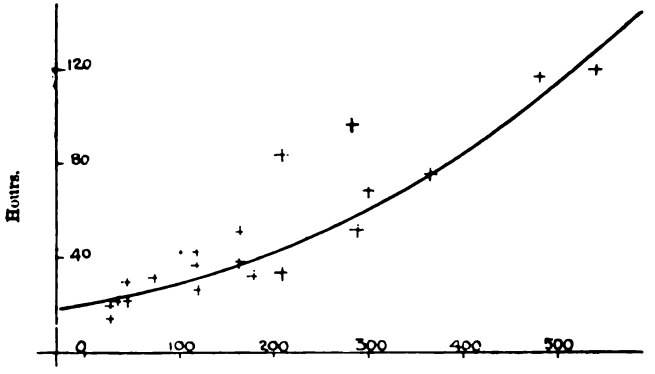
be entered in there. But if such entries are to be of any use afterwards they must be very clearly described, both as to the exact character of the job and its size, &c. If there is anything in the time sheet that is not clear, the timekeeper must go to the man concerned to ask him for particulars. It cannot be too strongly urged that the success or otherwise of this scheme depends entirely on the intelligence with which the foreman supervises the filling-up of the sheets. If it is left to the men themselves to put down what they think proper the whole thing will be a hopeless muddle, the only result of which will be to waste the timekeeper's time and ruin his temper.

Time Curves.—A couple of examples are given on pages 98 and 99, taken from the author's own observations, of the time curves referred to above. The points marked on the curves are representative of a large number of others. In the case of a number of articles of the same size, and made to the same drawings, the greatest and least times only are given. In inspecting the curves one is struck by the wide variation of the time occupied and the irregularity of the points of which the curves represent the mean. There are, of course, many reasons which may account for this feature. The most important is the essential defect in the method of plotting the curves arising from the impossibility of determining a strictly accurate scale for the base line. Articles of the same class and of the same size vary considerably in design, especially in the case of a shop doing general engine work—for instance, in which there is not a well-marked standard design. This was the case in the shops to which these curves refer. Another is that the quality of the man employed varies very greatly. Another, that there may be special difficulties in working to a particular design, or a particular casting may be very hard, or one machine tool may be very much superior to another. Indeed, unless the designs are all uniform, the tools employed all of the same class, and the men endowed with

equal skill, it will be found impossible to keep the points very close to the curve.

There is, however, nothing mysterious or indeterminate about the time taken to do a job. That is to say, the same man on the same machine will always do the same job in very nearly the same time unless there is some reason—such as specially hard stuff, for instance—why he should not. Another man of equal skill, on the same machine, will also occupy the same time if he adopts the same method.

The first of the illustrative curves here given shows the relation between the product of length and diameter of a cylinder and the time taken, in the shops to which we refer, to bore and face the cylinder and stuffing box, which, in this

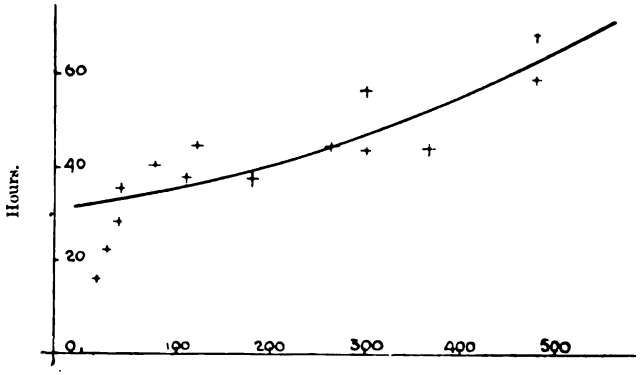


Value of length × diameter of cylinder bore.

BORING AND FACING CYLINDERS.

case, were cast in one. The boring was done in the majority of cases on rather old machines with only one cutter working. There was one particularly old-fashioned machine, generally worked by an apprentice, to which the upper points refer. The next shows the relation between the same abscissa as in the preceding case, and the time taken to turn and finish the connecting rod. Looking at the general shape

of the curves (which will be found to be the same in every case), it will be seen that there is a certain time spent in manipulating the apparatus, adjusting the machine tool, and similar things which cannot be dispensed with, however small the work may be. The larger the cylinder gets, the more nearly proportional is the time occupied to the size of the surface machined. There are many useful deductions which may be drawn from a careful inspection of such curves



Value of length × diameter of cylinder bore.

TURNING CONNECTING ROD.

as these. For instance, in the case of an old machine such as that mentioned above, it becomes a mere matter of calculation for the manager to determine whether or not it is worth while to keep the machine at work or to put it on the scrap heap, a place where, if the proprietors only knew it, a great many of the machines in many small shops ought to be, if it is desired to save money. The manager of a well-known American workshop recently remarked that every tool in regular work in a shop ought to be replaced by a new one every ten years. Though this may be an exaggeration, there is no doubt that in a great many cases proprietors keep tools at work long after it would be

decidedly economical to put them on the scrap heap or to sell them for what they will fetch. By transferring any workman to different machines it is an easy matter to eliminate the difference due to the workman from that due simply to the machine. The points referring to one workman on the same machine will be found to lie on a fairly regular curve, provided the class of work is constant. If any article made to a particular design is found to occupy always more time than it ought to do, judging from the height of the curve at the corresponding point, it is clear that there is probably something in the design that requires modification, and it becomes the foreman's or the manager's duty to inquire into the cause of the discrepancy. He will easily be able to tell whether there is any reasonable cause for any difference that exists. In fact, the curves furnish exact information, which may be put to such a variety of uses, that it is impossible to enumerate them all. Again, the knowledge that the time results have to be plotted on curves, and that any discrepancy will be inquired into, will keep the foreman up to the mark both in seeing that the time is correctly entered, and that no more time is spent on the job than can possibly be avoided. If the foreman knows that any figures that are put down will be allowed to pass without any remark being made or investigation undertaken, he cannot be expected to be as careful about the accuracy of the time sheets as he would otherwise be. In fact, the system involves several people's work, and is self-regulating as far as accuracy is concerned.

It will be shown in dealing with the distribution of work that there is to be a recognised way of doing every job, which must never be departed from. There are frequently several ways of doing almost every job in the place, all of which may be correct enough, but of which one is the best. It must be the foreman's duty to find out by accurate observation which is the best way, and to keep to that way under all circumstances, until he sees some very good reason for changing it. For instance, any of the following ways may

be used in machining a connecting rod: (1) Rough turning (by an apprentice); (2) finish turning (by a journeyman); (3) shaping the foot on the edges; (4) rough drilling bolt holes in foot; (5) sawing out the jaw; (6) slotting the jaw, or milling it out, to near the finished size; (7) boring the hole for the crosshead pin; (8) milling or slotting round the hole and on the cheeks; (9) planing the brasses; (10) sweating them together; (11) boring them out, &c., on an angle plate; (12) planing the cap or facing it in the lathe, and rough drilling it; (13) clamping all together, and finish boring the bolt holes, &c. Or the job may be done in the following order: (9), (10), (11), (12) (1) and (2) together, (4), (7) in a jig, (8), (6) after boring a hole at the bottom of the jaw, (13), and (3); or several other correct permutations of these operations might be made. Of course the brasses are, to some extent, an independent job.

Now, it is possible that there may not be much in it one way or the other, but whether there is or not, the foreman must adopt one or the other order, and stick to it throughout, both for the sake of economy in the shop and for purposes of timekeeping.

If he does not do so, not only will more time be spent on the job on the average, but the time records will have an indefinite meaning. For instance, if (7) is performed after (5) in order to obviate the effect of the springing apart of the cheeks when the cut is made, it will obviously occupy a good deal shorter time than if it (7) is done out of the solid, so that no comparison could be instituted between a man who had occupied, say, six hours after the jaw was cut out, and one who occupied, say, nine hours boring the hole out of the solid.

In a case of this kind the foreman should make a definite experiment to see which method is the cheaper, and he should stick to that which he finds to be the best in every case. The job numbered (7) will then have a definite meaning, as will all other jobs, and the manager will know that the records represent the same job in every case. If

there is any necessary variation, however slight, unavoidably introduced by some difference in the design (which variations should always be avoided where possible), the foreman must make a note fully describing this variation on the time sheet of the man concerned, and the timekeeper will then either omit the record from his time curves if the alteration is so serious as to warrant this being done, or make some note of it in the book. It will be obvious that uniformity in the curves cannot be looked for unless all the jobs to which the points refer are of an exactly similar kind, and considerable judgment will have to be exercised in determining which jobs may with advantage be plotted on the same chart. Thus, it would obviously be wrong to plot, without a note, the time taken in turning a piston rod with crosshead forged solid with the rod, on a curve of which the other points represent the time taken in simply turning a plain piston rod with a cone at each end. On the other hand, in a shop where the greater part of the work is made to special designs which vary a good deal, if it were attempted to plot each kind separately, the number of different curves might well become unmanageably great. Although in many cases large variations of design will be unavoidable, it is extremely desirable to keep the standard designs as uniform as they can possibly be made, and not to allow each individual draughtsman to alter the standard pattern at his own sweet will. There should be uniformity in the drawing office, as in every other department of the works. Great care should be taken to determine the best form for standard patterns, and then all designs should be made on the same plan, with definite gradations of sizes where possible.

All the curves should be drawn on large charts to a sufficiently large scale to allow of explanatory remarks being made on them where this is necessary, as will often be the case. Indeed, it is desirable to label each point plotted with the name of the man and the number of the machine. Certainly it makes the chart look extremely untidy unless

it is neatly done, but the curves are for use, and not for ornament. A constant careful inspection of the curves on the part of the manager and foreman is absolutely imperative if they are to be of real use.

Of course, experimenting with the work can be carried to absurd excess, just as anything else can. A foreman may alter, change, and shuffle about to such an extent, under the pretext of experimenting, that he gets no work done at all. In this, as in everything else, a happy mean must be sought between too much and too little. Experiments as to the best way of doing a particular job should be confined, as far as practicable, to the same man and the same machine, with the same stuff, on the same size of work, &c., so as to eliminate as far as possible all sources of error; and if the point is one of considerable importance, the observation should be repeated.

CHAPTER V.

Duties of Foremen.

There is no person employed in an engineering works who has more important duties to perform than the foreman. His duties are perhaps more worrying than those of any other official, and if he performs them conscientiously he has perhaps a harder life than anybody else, the manager not excepted.

We have repeatedly insisted that he must never under any circumstances be out of sight of his men. No foreman is capable of properly performing the duties for more than one shop, however energetic he may be. In a large works there is always a works manager, who exercises general supervision over the foremen, and who is entirely relieved of outside commercial duties. In a small works it is not uncommon to give the duties of works manager to the senior foreman, who has also to perform the duties of

ordinary foreman in one of the shops. We have no hesitation in saying that this arrangement is utterly bad. The chief, though by no means the only reason for this, is that it necessitates the foreman being away from the men directly under him, who receive all their instructions from him. Only those who have had to work under a foreman who has a general license to wander all over the establishment can fully appreciate the enormous waste of time that it causes.

To begin with, there is in every works a certain class of men who will take advantage of the absence of the foreman to idle away their time either in talking to other men or in playing pranks of some kind, or in doing work of their own. Especially does this apply to apprentices, who, if the foreman is known to be out of the way, will rarely do any proper work, but will either begin fighting or playing about, and getting in the way of the men. Some of them will make a model engine, or something else, in the intervals of absence of the foreman, putting the work away as soon as he returns to the shop. The foreman will sometimes under this arrangement have to be away from his own shop for half an hour together. While he is in the shop he is being appealed to every minute of the day by one or other of the men. If he is not there, on the spot, the man will generally wait till he comes back before going on with the work about which he requires the foreman's advice or instructions. He cannot be blamed for doing so. Very often it is impossible for him to go on with a job without special instruction. For instance, if he finds a mistake in a drawing, he has no business to go to the drawing office himself, and nobody but the foreman should ever be allowed to send any boy out of the shop. If he does not know which of two dimensions is right, he cannot possibly go on with the job without running the risk of spoiling it. He has therefore either to go and seek the foreman or idle away half an hour, both of which are positively ruinous to discipline. This is only a single instance of the

dozens of things that may arise which cause direct waste of time, not to mention the bad influence on the *morale* of the men generally.

In addition to this, the effect on the foreman himself is not less bad. He has a general license to roam about the works at his own sweet will, and naturally gets into conversation with other foremen, which is anything but a desirable example to set the men, and it tends to make him careless about his own department. He can only have a hazy sort of responsibility for everything. When anything goes wrong, it is impossible to fix the responsibility for anything definitely. Everybody concerned of course disclaims it. Each throws the blame on the other. It is, in fact, about as bad an amalgamation of duties as could be made to run a foreman and a works manager into one. It is, of course, imperative that there should be someone to form a connecting link between the various shops, but this must either be a general foreman—which is in reality another word for works manager—or the manager himself must undertake the duty. In a small works there is not enough for one man to do in this capacity, so that it ought to be part of the manager's duty to be works manager as well. Sometimes it is arranged that one of the other men takes the place of the foreman when the latter leaves the shop. This, again, is a hopeless expedient. It is impossible for any man in this way to take up at a moment's notice all the threads that a foreman should have in his hand. The arrangement produces a divided responsibility, and any arrangement that does this is of necessity bad. All the foremen should be on a level, and absolutely independent of one another, the only link between them being the works manager, by whatever name he is called. He distributes the work to the various foremen, and they see that the men do it properly. The foreman should have no more authority to go outside their own shops than the men have, although it is impossible to keep to this rule unless the works manager is always in the shop or easily accessible when he is wanted.

As regards the number of men that one foreman should

have under his immediate control, it depends entirely on the arrangement of the shop and the smartness of the foreman. It has been before remarked that a foreman ought to have a full view of the whole of his shop when he is in his office. This is not, of course, always possible, but the shops under control of one foreman should not be separated by a staircase or any serious obstruction, so that he can get to any part of the shop in a very short time, and that the men waste a minimum of time when they have to go to his office to seek him. He should be in his office as little as he possibly can. His proper place is not sitting down in his office, but walking about his shop with his eyes all over the place. Indeed, it may seriously be questioned whether he ought to have an office at all, as he has so little to do in it except keep a set of drawings there. But it will often happen that he may want to go somewhere to make a sketch, or a bit of calculation, or to think out the best way of putting a piece of work in hand, or to keep his various note books, or similar things. But the manager should carefully watch that none of the foremen regard their offices as convenient retiring rooms when they want to indulge in a little *dolce far niente*. It is really a very great temptation for a foreman to do this, as when things are going smoothly and work is a bit slack, and there is therefore nothing much to do, it becomes unspeakably wearisome to keep walking about the shop trying to find something to keep up the interest which every foreman who is worthy the name always maintains. It takes a strong and energetic man to keep his attention keen under all conditions.

It is by no means generally true that the best workman always makes the best foreman. He should have, in addition to a thorough knowledge of his trade, a power of organisation, a firm will, a quick eye, and a caustic tongue which he knows how to use—and how to refrain from using—when occasion requires, and last, but by no means least, a keen interest in his employer's welfare. Unless he has the latter he is not fit for his position, and those who have seen

a foreman's life from the inside will know well that a wise employer will not neglect to stimulate that interest by every means in his power. A foreman is in a position to be continually saving his employer money in a thousand different ways at the expense of a little care, forethought, or trouble on his own part, or to refrain from doing so without anybody but himself being any the wiser. If he has not a keen, active interest in doing so, he will not take the necessary trouble, and nobody but himself can by any possibility know that he has not done so. The policy adopted by so many employers of regarding the foreman as a convenient target for their ill-temper will be seen to be none of the wisest. A foreman should, in fact, identify himself with his employer, and the latter should take care that it is to his advantage to do so. This kind of interest is not merely a mechanical one. It is a state of mind, and cannot be manufactured to order at a moment's notice, and it is the outcome of mutual liking and stable financial arrangements between them. To expect a foreman to really put forward his best endeavours in behalf of a master who is continually cursing him, and who does not recompense him for or acknowledge in other ways any special exertion or successful effort, is to expect too much from human nature, and if such expectations are entertained they are foredoomed to disappointment.

Apart from the question of the shape of the workshop, the foreman should not have so many men to look after that he cannot keep clearly in his mind what each of them is doing. He should be able at any moment to say precisely what each man is doing, and know how far he has got on with the job, and he should also be able to keep in his mind when the job ought to be finished. He must know each man under him individually, both as to what he can do and how far he is to be trusted, and he may have just so many men under him, and no more, that he can keep all these particulars in his mind with regard to them all. It will be seen that he must be endowed with a good memory, but the effort is not so great as it would seem to be. Each job has an individuality

which enables the foreman to remember the particulars connected with it, much as a 'bus conductor can remember where each of his fifty-odd passengers has paid the fare to, He must fix in his mind long before a man has finished a job what he is to do next, so that there will be none of that "waiting till the foreman finds a job" that is so common in many works. He has to look ahead a good deal and plan out the work so that there may be the minimum of delay. He must be able to foresee that such and such a group of men will be short of work at such and such a time, so as to be able to provide for them, either by getting some stock work in hand or in pushing forward some work in the machines.

It is much better to keep the departments separate where this can be done, and have one foreman for the turners. and one for the fitters, and one for the machine-men; but this is not always or even usually possible in a small shop because of considerations of space, so that it will often happen that one foreman will have the superintendence of both fitters and turners. There is no objection to this if the foreman is both a competent turner and a competent fitter; but in any case the foreman ought always to be able to take the tools out of a man's hand and finish the job himself. If the men know that the foreman is not thoroughly master of his trade, it will be impossible for him to maintain his full influence. He must, in fact, be thoroughly "in the know" himself, or he will never be able to speak with that decisive voice that should be at the command of the foreman. Above all things, he must not be vacillating or weak. His word must be law as far as the men are concerned, and the manager or anyone else must not dispute that position with him. Although he may himself be quite willing to obey the manager's instructions, a first-class foreman will resent in the most vigorous and outspoken manner any overriding of his authority over the men by anybody whatsoever, and the kind of man that will submit to it is not generally a suitable man for the

position. Anything that the manager wishes to say to the men must be said through the foreman. Any other course will be absolutely fatal to the influence of the latter. A man must never be allowed to think that he can reverse the dictum of the foreman merely by appealing to the manager.

The foreman should be responsible for engaging or discharging the men and maintaining a due proportion between the various classes, if he has more than one class under him, and this should never be taken out of his hand if the foreman is to have his proper influence in the shop. Again, he should refrain from too great an intimacy with any of the men under him. "Familiarity breeds contempt." For this reason it is often thought desirable (and no doubt it is so to some extent) to appoint a new foreman from outside the works, and not to promote a journeyman to this important position, although the latter plan tends to inflict a sort of hardship on old hands, who are otherwise fit for the position. Still, if a man already employed in the shop is appointed, it invariably leads to heartburning among other men, each of whom, of course, thinks he was better entitled to the post from his superior abilities. Of course, when a man is already known to the masters as a steady, reliable man, with the necessary qualifications, it may be better to appoint him than a perfect stranger, who may perhaps turn out to be totally unfit to hold the position. Besides which, an old hand who has been with the firm for a long time may be reasonably expected to take a greater interest in the firm than a new importation; so that it is difficult to lay down a hard and fast rule on the subject.

The question as to how far the foreman ought to overlook a man is one of considerable importance. It must, of course, depend to a very large extent on the character of the man. In dealing with different men the foreman needs all the tact that he can use. There is a happy mean between laxness and officiousness that every foreman ought to strive after. Nothing tends to annoy and irritate a competent man so much as to have the foreman continually on his

track. In fact, there are men of whom it may be said that the less they have to do with the foreman the better. Many men hardly need any supervision at all, and they, being fully aware of this fact, will deeply resent any attempt to impose it on them on the part of the foreman. But it by no means follows that, because the foreman knows that they can quite safely be left to themselves, he should, therefore, neglect to notice what they are doing. He should be so familiar with the work himself that he can tell at a passing glance exactly what is going on; and if he does entertain a high opinion of a man, he should convince himself that the man is living up to it by continually, but unobtrusively, keeping his eye on his work. It is a very easy thing for an unobservant foreman to have this opinion of a man for a long time, when, in fact, he is actually much below other men, both in the quantity and quality of the work that he can turn out. Unless there is some actual exact system of recording, such as has been already described, the opinions of the foreman are of necessity unreliable. He has his prejudices, and likes and dislikes, and they will in many cases blind him to facts which are more or less obvious to others. There is less danger of this happening when the actual times and particulars relative to the various men are booked, and systematic records kept of them.

Wages cannot be altogether determined by the booked results, although they ought to be so to a very large extent. Of course, the men ought not to be allowed to see the time records, otherwise it will cause a good deal of friction. If a man who is in receipt of 38s. sees that his time records are as good as or better than those of another man who may be getting 40s., the former will at once make application for the 40s, when there may be many reasons for the second man having better pay, which would by no means appeal to the first, even if they were fully explained to him. The firm should keep all their information for their own use, and should certainly not allow the men to have access to it.

The foreman should be able to keep in his mind when each job may be expected to be finished. Every time he gives out a job he should enter in the Work Book the time allowed for it. This will suffice to fix it on his mind, and will compel him to take notice of such matters when he might otherwise overlook them entirely. He should not fail to remind the man that he has exceeded this time if such is the case. This will serve to keep continually before the men the fact that they are being judged on their merits, and will have a very stimulating effect on them. But the time should not be made so short that the shop gets the reputation of a slave-driving establishment, nor should men be needlessly reminded that they have exceeded the time allowed if it is only by a very small trifle. And they should certainly not be told if they have been much quicker than the recognised time, for this may make them self-opinionated, although this fact should by no means escape the notice of the foreman himself.

Speed of Tools.—One of the most important of the duties of the foreman is to see that the tools are run at their proper speeds, and also that the proper depth and width of cut are being taken off. This is a point the importance of which it would be difficult to overestimate. The rapidity with which a job is finished is, *ceteris paribus*, almost proportional to the continued product of the speed at which the tool is run, with the depth and width of the cut. In an ordinary shop there are very few tools which run at their full capacity. For roughing cuts the limiting speed is that at which any increased time gained by speeding up is equal to the loss of time due to the greater frequency with which the tool must be changed. At this point the tool is working at its maximum capacity. It appears to escape the notice of engineers generally that the use of Mushet and other self-hardening steels for the tools largely increases the capacity of the machine. The use of such steel is prohibited in a great many shops owing to the increased cost, when, as a matter of fact, the difference in cost between a tool made of

ordinary and a very good steel would in some cases be paid for in a single day by the increased productiveness of the machine. This is another example of the economy which has such disastrous results in many modern shops. It may be taken as a general axiom that any money laid out in buying tools or in getting the very best that money can buy is money saved a hundredfold. Any so-called economy in this direction is, in reality, the most reckless extravagance conceivable. The fact cannot be brought home to the minds of engineers until they adopt the system of making accurate observations such as those we have been describing. When this is done, it only needs a piece of paper and a pencil to convince them of the monumental folly of sparing outlay on tools. The blindness of many masters in this direction is almost incredible. Many a master would feel less aggrieved at having to pay £100 in wages than if his foreman were to ask him to spend £10 in buying improved tools to save it. With many masters it would be almost as much as the foreman's position was worth to seriously suggest any extensive outlay of this character. This question of the speed of tools is of the most vital importance, and we shall therefore, consider it at some length.

Speed of Engine.—To begin with, the importance of having the shop engine properly governed is a matter the necessity of which is very often overlooked. If the shop shafting is running at one time at 100 revolutions per minute, and at another time at 80 (this is not by any means an uncommon variation in small shops), the men will set their tools at what they think is the correct speed for the 100 rate. When the speed falls very few of them will shift their belts, and the consequence will be that their tools will run 20 per cent under what even they think is a suitable speed. When the foreman makes a complaint they have a ready-made excuse, that half a minute before the engine was running very much faster. This may or may not have been the case, but whether it was or not, it provokes a dispute between the foreman and the man, which may lead to high words if they

are both of uncertain temper. It is unnecessary to point out the undesirability of this state of things. What is important is that all these possible causes of friction should be removed. It is quite possible to govern an engine to within 1 per cent of the mean, but even much less accuracy than this would be sufficient in an engineer's shop. The engine ought invariably to be provided with a speed indicator, and, if possible, an autographically recording one. This keeps the engine-man up to the mark. If the foreman or the manager goes into the engine-house, and finds the engine running below normal speed, it should be the certain signal for unpleasantness between him and the engine-man.

It is very desirable to supply the boiler with an automatically recording pressure gauge.

Speed of Machines.—A constant speed of the shafting having been thus secured, it remains to ensure that the men maintain the proper cutting speed on the tools. This is a most difficult thing to do. Except in those shops which work on the piecework system, there is little inducement to the men to try to get the best results from a machine. Whether it is due to the natural conservatism of the British workman, or his laziness, or to the fact that from his apprentice days he has imbibed and absorbed the principle of restriction of output so that it has become part and parcel of himself, the fact remains that it is a most difficult thing for the foreman to induce the men to maintain the tools at the proper speeds, and it is only comparatively few employers who recognise the extent of this evil. It is not by any means confined to the unionist section of the men; non-unionists are almost, if not quite, as bad. The remedy is to be found in a strong foreman, who has accurate means at his disposal for instantly detecting exactly what is the actual speed at which a tool is running at any time, and a well-recognised rule which must not be departed from, except on his express instructions. Some latitude must be allowed to him, because the best speed will vary with the hardness of the metal operated on and with the quality

of the tool steel, and other matters. It may be said that a "practical man" can tell at a glance whether or not the tool is running as fast as it ought to do. The fact is, however, that prejudice and custom have such a great deal to do with what a man thinks is the correct speed, that it is not safe to rely on the eye alone. Nothing that can be determined by accurate observation should be left to anybody's judgment, no matter how "practical" he may be. In the present case it is particularly easy to observe, instead of judging, if a proper method be adopted.

There is another fact which makes this duty of a foreman still more difficult. It is well known that both the depth and width of a cut can be made greater when the speed is lower, and many a workman (and foreman, too) often thinks that a job will be more quickly finished if the slower speed is adopted, and an extra heavy cut put on to compensate for the lower speed. Now, it has been already pointed out that what is really desirable is to remove the greatest amount of metal in the shortest time—that is to say, to so fix the three variables, speed, depth, and width of cut, that their product is a maximum. Careful and very elaborate experiments have proved that in a general case this will be secured by keeping the speed up to certain values, and making the depth and width of cut as great as they can be at that speed. Now, in practice, although with specially stiff tools these speeds may often be greatly increased, they cannot be maintained under all circumstances, owing to a variety of causes with which we shall briefly deal. First, however, we shall give the speeds which are the best for ordinary tools and material in the opinion of the most competent authorities. They are as follow :—

Turning: Cutting speeds—

Cast iron.....	175	to	250	in.	per minute.
Steel.....	250	„	300	„	„
Wrought iron	300	„	450	„	„
Gun-metal, soft.....	300	„	450	„	„
Gun-metal, hard.....	250	„	300	„	„
Brass.....	450	„	1,200	„	„

Boring:

Cast iron.....	125	to	150	in.	per minute.
Steel.....	150	„	225	„	„
Wrought iron.....	200	„	300	„	„
Gun-metal.....	150	„	300	„	„
Brass.....	300	„	800	„	„

These speeds must not be by any means considered as the maximum. With very good appliances they may often be largely increased with advantage. Strictly speaking, every tool has its own best speed. These are a fair average for ordinary conditions.

Drilling: Peripheral speed of drill—

Cast iron	175	to	200	in.	per minute.
Steel	175	„	250	„	„
Wrought iron.....	250	„	300	„	„
Brass.....	300	„	500	„	„

With really good drills, well lubricated, these speeds may often be largely exceeded. The writer has had drills working quite satisfactorily at double the speeds given here.

Force on drill head = about 1,500 lb. × diameter of drill in inches.

Feeds:

Up to $\frac{1}{2}$ in.	200	revolutions to	1 in. feed.
$\frac{1}{2}$ in. to $1\frac{1}{4}$ in.	150	„	1 „
Above $1\frac{1}{4}$ in.	100	„	1 „

Planing.—For some unknown reason, planing machines are only made with one speed, so that tables of speed can be of little use. The speed usually adopted in the cutting stroke is about 180 in. to 250 in. per minute. If it is less than this, the pulleys should be altered on the countershaft. Many planers will run quite satisfactorily up to 250, and even more. It would be often a great advantage if planing machines could be run at different speeds according to the metal operated on. There should be little difficulty in modifying the design of these machines to allow of this being done.

Shaping.—150 in. to 180 in. per minute in the cutting stroke is the speed usually employed. Every shaper ought to have quick-return motion.

Milling.—Peripheral speed of cutters, for—

Cast iron	650 to	700	in. per minute.
Steel.....	400 „	500	„
Wrought iron	500 „	550	„
Gun-metal	500 „	1,000	„
Brass	1,000 „	1,500	„

We shall now deal with the reasons which in practice may modify the actual cutting speeds which can be employed.

If a too high speed is employed in conjunction with a too severe cut, one of the following effects may be produced :—

(1) The belt may slip or break.

(2) The point of the tool may be heated, softened, or "burnished" in a very short time, so that the time spent in grinding and setting the tool more than counterbalances the gain of time due to increased speed.

(3) The machine or the work may be strained, the bearings may heat, or the tool may be broken.

(4) The work may begin to chatter or tremble, causing the cut to be uneven, and thus hastening the damage to the edge of the tool. The work may be pushed away from the tool by the strain that comes on it, so that the tool does not actually take off the quantity which it ought to do geometrically.

If all these effects could be obviated, there is no limit to the speed which might be employed with advantage.

It will be thus clear that the secret of high speeds and heavy cuts are as follow :—

(1) Broad belts and high belt speeds and pulleys which are not too much rounded. (This is a very common cause of belt trouble in the workshop ; the pulleys are given so much belly by the maker, that the belts only touch them in the centre, and, therefore, are deprived of a large part of their adhesive-

(2) The best material that can be bought for the tool itself kept flooded during the work with large quantities of lubricant. There appears to be a great and quite unwarranted prejudice among machine-men of all classes against keeping the point of the tool properly lubricated. The reason for this is not far to seek. When lubricant is used at all (which is by no means always the case), it is run on the work from a can, which is supported on the slide rest by a bracket. When this runs empty, the turner has to fill it from the trough which catches the drippings under the machine. This is too much trouble for him, so he runs the liquid on as slowly as possible, so as to save himself the trouble of re-filling it more often than he is obliged. The best way to overcome this difficulty is to have the lubricant laid on just as gas is, by a service of pipes leading from a cistern 6 ft. or 8 ft. above the level of the tools, and a properly designed series of troughs and pipes for catching the waste and leading it back to an underground tank, from which it is pumped to the cistern above. The troughs must be so made that they strain the lubricant before it passes to the pipes, which will otherwise get choked with small cuttings. The latter must also be arranged so that they can be easily taken to pieces for cleaning out. This method not only saves trouble to the workman, but it saves much of his time, and, further, should be exceedingly economical of lubricant, as it saves what would otherwise be splashed about the shop by the man when re-filling his can from the trough.

For supplying the lubricant to the point of the tool an excellent plan is to use steel with a groove on the underside. In this groove is a small tube leading from a cistern at a considerable height above the tool, which tube is turned up towards the point at the working end. This device squirts the lubricant just where it is wanted on the point of the tool, and in that respect contrasts favourably with the ordinary method of pouring it on the top of the shaving, where it cannot reach the cutting point of the tool at all.

It is by the judicious use of such methods as this, combined with adequate support to the work and the tool, that high speeds and heavy cuts become possible, and it is surprising that so little attention should be usually devoted to this very important matter. For very heavy work, such as that done by capstan lathes, a special pump is provided which keeps the tool flooded with thick grease, which is commonly lard oil. This being expensive, the cuttings are often put into a centrifugal machine, in order to recover the oil which adheres to them. In any case, however, the loss of oil is considerable.

It is quite common to see shops where no lubricant at all is employed, except for the finishing cut, when dirty water is merely dabbed on with a brush or a piece of waste out of an old coffee canister, the object being to save the few coppers necessary to buy a proper can with a cock. In other cases the management will not allow the use of anything but water for this purpose, on account of the expense of soap and soda, and the result is that if the tools happen to be left standing for a day or two they are rusted solid, and as much money has to be spent in getting them into order again as would supply the whole shop with soap and soda for a couple of months. In other cases, where the outlay for soap and soda is made, the troughs to catch it in are in such a decrepit state that more soap leaks through them in a single day than the new troughs are worth. As we have said before, such economy is in the highest degree praiseworthy when it *is* economy. A considerable sum of money may easily be saved in a year by the observance of economy in trifles. But the pity of it is that proprietors will not go to the trouble of *observing* what is the result of their "economies," and therefore do not economise with discretion. Broadly speaking, it may be truthfully said that any small economy effected at the cost of any waste of time is, in reality, a very expensive sort of economy indeed. It is to be feared that in an engineer's shop most of the small economies that can be effected are

of this kind, and they should be indulged in with the utmost caution. It is so much more easy to see the value of a candle, for instance, than five minutes of a workman's time, that there are few employers who would, without a protest, see a workman waste a whole candle in order to save himself five minutes' trouble. A moment's reflection would convince him that five minutes of a workman's time was worth just about two candles; but he does not think of that. He can see the candle, and he cannot see the time slipping past. He adopts the same attitude with regard to all small things that are required in such large quantities in the shop, the result of which policy is only seen on the balance-sheet.

(3) This difficulty is overcome by making the machine not only very strong, but also very stiff. Old-fashioned machines are very often very defective in this respect. If a machine is not stiff to begin with, it can never be made so. This fact alone should justify the selling or scrapping of any machine that will not stand up to a good speed with a stiff cut. No satisfactory and economical work can be got out of such a machine, and it is the best policy to replace it as soon as possible.

(4) This is caused by lack of stiffness either in the machine or in the work itself. When only one tool is at work with a heavy cut on a job (such as a hydraulic ram, for instance), there is a tendency for the tool to push the work out of the way. The tool point will stick in the work for an instant, till the force due to the "give" of the job or the machine becomes great enough to start the cut again, when it goes with a jerk, and then sticks again. The result is that the tool cuts with a series of jerks. This is highly prejudicial both to the cutter, the machine, and the work. The trouble is remedied by making the centres very stiff, and by supporting the work by a strong travelling stay on the saddle, and also by getting two tools at work on the job, one on the front, and one opposite it on the back of the job. Unless they are specially ordered to do it, many men will not use travelling

stays, even when they are fitted to the machine, on account of the trouble of rigging them up.

It will often be found to be the case that it will not be possible to take a first roughing cut off a job at the proper speed, but subsequent cuts, if any, may be run at that speed. This is owing to the great variations in the depth of the cut which will be found on a first cut, due sometimes to the job not being perfectly straight. In general one roughing cut and one finishing cut should suffice for most jobs.

Speed Cones of Lathes.—It will be noticed that in the tables of speeds given on pages 115 and 116 there is considerable latitude allowed. This is due to a great many causes, some of which have already been referred to. It is chiefly, however, due to the essential defect in almost all machine tools, viz, that they are not continuously adjustable for speed, but proceed by steps. This is a serious defect in any case, but it is made a great deal worse by the great carelessness with which most lathes and other tools are designed. The speeds for steel, for instance, are given as from 250 in. to 300 in. per minute. Now, it will often be found that between two successive speeds in a lathe, for instance, there exists a great gap.

The following is one of a great number of examples of this feature of many tools observed by the author :—

	Time of one revolution.		Time of one revolution.
Fore gear, speed 1.....	0·42	Back gear, speed 1.....	5·2
„ „ 2.....	0·61	„ „ 2.....	7·5
„ „ 3.....	0·96	„ „ 3.....	12·0
„ „ 4.....	1·58	„ „ 4.....	20·0

Now, it is clear in this case that, suppose it were desired to turn a steel shaft whose diameter was 4½ in, if the belt were put on the first pulley back gear the cutting speed would be 160 in. per minute. This would rightly be considered much too low. But suppose the belt were put on the next available speed, viz., fourth pulley direct gear, the cutting speed would then be no less than 540 in. per minute, which might well be much greater than the machine or the work

would stand. This example will illustrate the importance of all machines being very carefully speeded by their makers. In a case like this it is well to give instructions that the machine is not to be used for work between certain diameters. This restriction is often a great nuisance in practice, but it is the only thing that can be done. It is really surprising how little attention appears to be paid to this point by makers of machine tools, and managers of works should be very careful in purchasing tools that the speeding has been properly designed. This is not by any means the only defect which is commonly found in lathes and other tools. In a great many it is not possible to put on as broad a feed as the machine will stand because the feed gear will not allow of it. In some cases the only possible way to get a broad feed is to use the leading screw. The strap feed is often so flimsy and badly designed, that the feed belt slips off the pulley when a broader feed is put on.

The foreman should not rest satisfied that a machine is doing all it can without trying whether it will not do more. If he is prepared to accept without ocular demonstration the random statements of the workman that the machine will not do more than it is doing, he might as well go home. He should insist on heavier and heavier cuts being put on, till the machine shows unmistakably that it will not do any more, and order the man to run at that. The remarkable solicitude which many men will exhibit for the safety of the machine during this operation should not deter him from convincing himself that it is doing as much as it can. This is absolutely the only way that machines can be run at their best.

Now, it is clear that, the speed of the engine being constant, if the proper speed for a 2 in. steel shaft is the fastest speed on the back gear at one time, it will also be the correct speed at any other time for the same or similar material, and it is clear that the diameter of work which must be done on that speed can be exactly specified. It is therefore obvious that a speed table should be supplied to

each machine tool, regulating the speed for any diameter, and no slower speed should be allowed, except on the express instructions of the foreman. This latter proviso is essential, because any material varies greatly in hardness and in other respects, and if any piece of stuff is so hard as to make the regulation speed impossible, the foreman can be easily convinced that such is the case, and will give the man permission to modify the speed accordingly; but he should not do this without experimentally satisfying himself that there is very good reason for it.

The following method is used by the author in drawing up tables of speed, and will be found to answer every purpose.

A careful draughtsman or some other reliable person is instructed to observe experimentally the speed at which every machine in the shop runs when the gear and belts are varied. A complete series of notes are taken of these, and the results afterwards embodied in speed tables, one of which is supplied to each machine. There is a difficulty in making the tables exact, owing to the fact that the speeds at which the machines run when doing their work is different from that when no load is on. This arises from the slip of the belts, so that an observation taken when the machine is under no load is of necessity unreliable when applied to a machine under load. It is impossible to remove this difficulty entirely, except when electric driving is employed, as the slip of the belts depends on their tightness and their condition as to dryness, both of which are, of course, variable quantities. The difficulty is partly removed by deducting from the observed speed a fixed percentage (10 per cent is a good value to adopt), thereby estimating that a machine which makes one revolution in 0·9 second when under no load, will occupy 1 second when doing its work. The proper diameter of work for that speed is then calculated on this basis. It will be found that by far the most convenient way of observing the speed of a tool is to find the number of seconds occupied in making one revolution, and discarding

the common method of finding the revolutions per minute. The reason for this will be obvious to anyone who has to deal with this matter in practice. It may be observed that a good stop-watch is simply invaluable in making speed observations, and every foreman should be supplied with one, as they are not expensive. The best kind of watch for this purpose is one which has a centre-seconds hand which is at rest until the winding stem is pressed. This starts the chronograph mechanism. A second pressure on the knob stops the chronograph mechanism, and a third returns the hand to zero. With a watch of this kind a speed observation can be made without removing the watch from the pocket. If the speeds are calculated on the basis of the number of revolutions, or the speed per minute, the observer has to keep his eye both on the watch and on the revolving body, and his observation is certain to be inaccurate, because not only is it impossible to look at two things at once, but also because he cannot estimate accurately fractions of a revolution, especially when at least half of his attention is concentrated on the face of the watch, in order to note the exact end of the interval during which the counting is taking place. Without doubt, the best way to take a speed observation is to make a chalk mark on the face plate, and when it is passing a certain fixed point press on the knob of the watch. Count either 100, 10, or one revolution, according to the speed of the machine, and when the chalk mark is passing the same fixed point stop the watch, which will then indicate exactly, and without any calculation, the time of one revolution when the decimal point is adjusted. A reference to the table given on page 127 will then give the exact cutting speed at which the tool is running.

The draughtsman should use this method when speeding the machine, and should repeat all observations at least twice. His observations will read as follow :—

MACHINE NO. .....

Speed.	Time of one revolution.	Estimated time of one revolution under load.
Fastest		
Second		
Third		
Fourth		
Back gear.		
First		
Second		
Third		
Fourth		

When these observations are completed, he should draw up a table for that machine, ruled as follows :—

SPEED TABLE.

Machine No. 7.

Speed.	Time of one rev.	Cast iron.		Steel.		Wrot. iron.		Brass.	
Fore gear :		From	To	From	To	From	To	From	To
Speed 1 (fastest)	0·75	Up to	1 in.	Up to	1¼	Up to	1¾	Up to	3¾
2	1·40	1	1¾	1¼	2¼	1¾	3½	3¾	7
3	2·50	1¼	3¼	2¼	4	3½	6½	7	13
Back gear :									
Speed 1	7·0	6½	9	9	11¼	11½	18	Above	13
2	13·0	9	17	11¼	20	Above	18		
3 (slowest)	23·7	Above	17	Above	20				

NOTE.—No slower speed than that given in the table must be used, except on the express instructions of the foreman.

Each speed table when made will be pasted on a board and varnished, and hung up over the corresponding machine. It must be well understood that the tables are for use and

not for ornament, and that any necessary departure from these speeds, due to specially hard metal or other cause, must be reported to the foreman. The latter should be continually on the look out that this rule does not become a dead letter. He should not be satisfied that the table speed is being kept to, but should be continually making observations as to the actual speed maintained by means of his stop-watch. This serves as a check on the tables. He will often find that the job will stand the next higher speed, and in that case should insist on its being put on. He should know enough about his trade to be able to convince his men that he knows what he is talking about, and should certainly not allow his decisions on this important point to be questioned.

There will be no calculations needed in drawing up this table if the person doing the work refers to the table printed below on page 127. The figures given in the speed table on page 124 are taken from one of a large number of actual tables drawn up by the author, and refer to a 3-speed lathe of which the speeding is very bad.

It will often be found that, owing to the careless design of machines, wider limits of speed will have to be allowed than are given on pages 114 and 115. This cannot be helped, and is due simply to the bad design of the tool. The ratio between any two successive speeds of a machine tool should not be greater than 4 to 3, and they should be constant—that is, there should be the same ratio between the second and third speeds as there is between the first and second, and so on. This provision, of course, restricts the diameter of work that can be done on the machine unless the number of speeds is largely increased, but in practice a large lathe is rarely used for doing small work, so that the disadvantage is more apparent than real.*

For instance, in the specimen speed table given on page 124 it will be observed that the speeds allowed for steel are,

* At least one fairly quick speed is necessary on most lathes, for use in polishing or finishing.

on the first speed, up to 315 in. per minute; on the second, from 168 to 304; and on the third, from 170 to 301.

Exactly similar tables are to be drawn up in the case of drilling and milling machines, the figures in the columns referring to the sizes of the drills or milling cutters, and, in the case of shaping machines, to the length of stroke. In the latter case, where the machines have quick return motions, the time of the *cutting stroke* must be found exactly, either by observation or by finding the ratio between the time of cutting stroke and the return stroke, and, the exact time of the double stroke being determined by observation, the cutting portion can be exactly found by calculation.

As planing machines are only made with one speed, the only thing to be done in these cases is to see that the speed is correct, and, if not, to alter the pulleys or the gear wheels till a speed of 200 in. per minute is obtained. The author knows several planing machines which work quite satisfactorily at 250, and others which will not work above 200, owing to want of stiffness.

When the table printed on page 127 is not at hand, it is convenient to observe that the correct time of a revolution for the various materials is given approximately by the following rule:—

Material.	Time of one revolution.	Corresponding speed.
Cast iron.....	1 × d to 0·8 × d ...	188 to 237
Steel.....	0·8 × d to 0·6 × d ...	237 to 315
Wrought iron...	0·6 × d to 0·4 × d ...	315 to 474
Brass	0·4 × d to 0·2 × d ...	474 to 940

Where d is the diameter of the work in inches.

These speeds, it will be seen, correspond closely to the actual best cutting speeds given on page 114.

The following table will save much calculation in this connection:—

TIME OF ONE REVOLUTION (SECONDS).

Speed in inches per minute.

Dia.	100	125	150	175	200	225	250	275	300	350	400	450
¼	·470	·375	·315	·270	·236	·210	·189	·172	·157	·134	·118	·105
⅜	·940	·750	·632	·540	·472	·420	·378	·345	·314	·268	·237	·210
½	1·41	1·12	·950	·810	·710	·630	·565	·516	·470	·402	·354	·314
1	1·88	1·50	1·26	1·08	·944	·840	·755	·690	·630	·537	·472	·420
1¼	2·35	1·88	1·58	1·35	1·18	1·05	·946	·862	·788	·673	·591	·525
1½	2·83	2·25	1·90	1·62	1·42	1·26	1·14	1·04	·943	·808	·710	·630
1¾	3·30	2·63	2·22	1·89	1·65	1·47	1·32	1·21	1·10	·940	·830	·735
2	3·76	3·00	2·53	2·16	1·88	1·68	1·51	1·38	1·26	1·07	·945	·840
2¼	71	3·7	3·	2·70	2·36	2·10	1·89	1·72	1·57	1·34	1·18	1·05
3	5·66	4·50	3·78	3·24	2·83	2·52	2·26	2·07	1·88	1·61	1·42	1·26
3½	6·60	5·25	4·42	3·78	3·3	2·95	2·65	2·41	2·20	1·88	1·66	1·46
4	7·52	6·00	5·05	4·32	3·77	3·35	3·02	2·76	2·52	2·15	1·89	1·68
4½	8·50	6·75	5·70	4·85	4·25	3·78	3·40	3·10	2·83	2·42	2·13	1·88
5	9·40	7·50	6·32	5·40	4·72	4·20	3·77	3·45	3·14	2·69	2·37	2·10
5½	10·4	8·25	6·95	5·94	5·20	4·61	4·15	3·80	3·45	2·95	2·60	2·30
6	11·3	9·0	7·60	6·5	5·65	5·04	4·53	4·14	3·77	3·22	2·83	2·52
6½	12·2	9·75	8·20	7·00	6·12	5·45	4·90	4·46	4·10	3·50	3·06	2·73
7	13·2	10·5	8·83	7·55	6·52	5·87	5·30	4·80	4·40	3·75	3·30	2·93
7½	14·1	11·2	9·45	8·10	7 10	6·30	5·65	5·15	4·71	4·04	3·54	3·15
8	15·0	12·0	10·1	8·61	7·56	6·70	6·05	5·50	5·02	4·30	3·78	3·35
9	16·9	13·5	11·4	9·70	8·50	7·57	6·80	6·20	5·66	4·84	4·25	3·77
10	18·8	15·0	12·6	10·8	9·44	8·40	7·55	6·90	6·3	5·37	4·72	4·20
11	20·7	16·5	13·8	11·9	10·4	9·25	8·30	7·60	6·91	5·91	5·20	4·61
12	22·6	18·0	15·1	13·0	11·4	10·1	9·10	8·27	7·55	6·48	5·66	5·04
14	26·4	21·0	17·6	15·1	13·2	11·8	10·6	9·65	8·82	7·55	6·63	5·93
16	30·1	24·0	20·2	17·3	15·1	13·4	12·1	11·0	10·1	8·61	7·58	6·73
18	34·0	27·0	22 7	19·4	17·0	15·1	13·6	12·4	11·3	9·70	8·51	7·58
20	37·5	30·0	25·2	21·6	18·9	16·8	15·1	13·8	12·6	10·8	9·08	8·40
22	41·4	33·0	27·7	23·8	20·8	18·4	16·6	15·5	13·8	11·8	10 4	9·25
24	45·1	36·0	30·2	26·0	22	20·1	18·1	16·6	15·1	12·9	11·4	10·1
28	52·5	42·0	35·2	30·2	26·5	23·5	21·2	19·3	17·6	·0	13·2	11·8
32	60·0	48·0	40·3	34·5	30·4	27·0	24 2	22·1	20·2	·2	15·2	13·4
36	67·8	54·0	45·4	39·0	34	30·2	27·2	24·9	22·7	19·4	17·0	15·1
40	75·0	60·0	50·4	43·3	37·8	33·5	30·2	27·6	25·2	·5	19·0	16·8
44	82·8	66·0	55·4	47·5	·6	37·0	33·2	30·4	27·7	23·7	20 8	18·4
48	90·0	72·0	60·5	51	45·5	40·4	36·5	33·2	30·2	25·8	22·7	20·2
56	106·0	84·0	70·1	60·5	53·0	47·0	42·5	38·6	35·2	30·1	26·5	23·5
64	121	96·0	80·1	69·1	60·7	53·7	48·5	44·1	40·2	34·5	30·8	26·8
72	136	108	90·5	77·8	68·0	60·5	54·5	49·6	45·2	38·	34·0	30·2
80	151	120	101	86·4	75·5	67·1	60·5	55·2	50·4	43·0	37·8	33·5
88	166	132	111	95·0	83·2	74·0	66·5	61·0	55·4	47·4	41 5	37·0
96	181	144	121	104	91·0	81·0	72·5	66·3	60·5	51·6	45·4	40·2

The following figure gives the same results continuously, instead of by steps :—

EXAMPLE.—**If a cut 45 in. in diameter is being taken in a lathe, and one revolution occupies 35 seconds, the cutting**

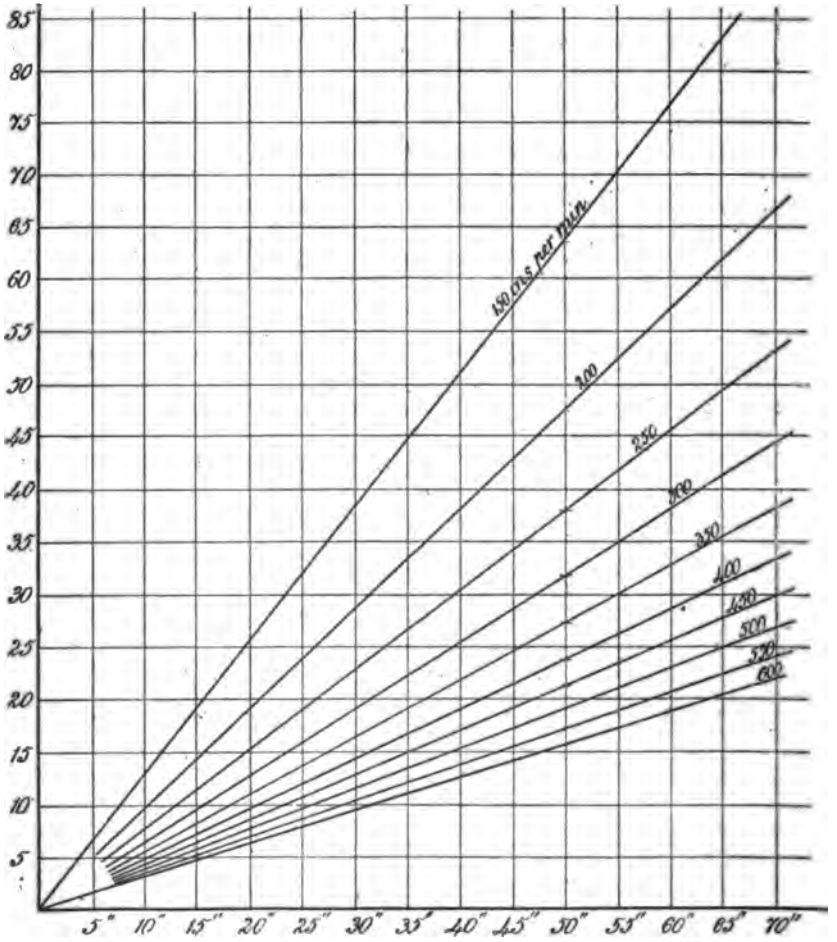

85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
150 cubs per min.
200
250
300
350
400
450
500
550
600
5" 10" 15" 20" 25" 30" 35" 40" 45" 50" 55" 60" 65" 70"
Diameter.

FIG. 3.

speed is nearly 250 in. per minute. This is found by following the vertical line marked 45 in. to a point where it cuts the horizontal marked 35 seconds. The point nearly lies on the line marked 250.

The figure on page 130 gives the speed corresponding to various lengths of cutting stroke made in various times. For instance, if a planing machine, taking a cut of 67 in., occupies 20 seconds in making the cutting stroke, the cutting speed is about 200 in. per minute. This is found by following the vertical line, representing 67 in., to the point where it meets the horizontal line, representing 20 seconds. This point will be seen to lie on the line marked 200, showing the cutting speed.

Width and Depth of Cut.—These are only limited by the strength and stiffness of the machine and the work. The proper depth and width of any cut is the greatest which a machine will stand.

Lathes.—For heavy work, say above 5 in. or 6 in. in diameter, a width of as much as $\frac{1}{4}$ in. can sometimes be taken off per revolution, though under ordinary circumstances better results are obtained with $\frac{1}{8}$ in. Finishing cuts should be as light as possible with a flat pointed tool, and as broad a feed as the machine will give. The feeds allowed for in many, if not most machines, are much too small. Except for small work under 1 in. in diameter, or very fine work, nothing less than $\frac{1}{16}$ in. per cut need be used, and as deep as the machine will take. For ordinary work, on which a very accurate finish is not required, no more than one roughing cut and one finishing cut should be taken.

Planing Machines.—Very strong machines can sometimes be worked up to a cut $\frac{1}{3}$ in. broad; $\frac{1}{2}$ in. is a more usual feed. Finishing cuts should be light and very broad up to $\frac{1}{2}$ in. wide, taken with a flat broad tool. One complete turn, and in some cases two, of the feed screw put on by hand is usual for finishing cuts.

Shaping and Slotting Machines take from $\frac{1}{12}$ in. to $\frac{1}{20}$ in. per cut, with, as before, broad finishing cuts.

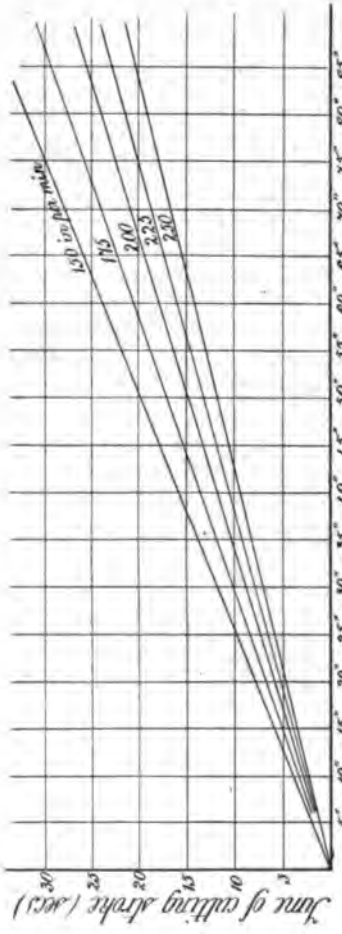

150 ins per min
175
200
225
250
5" 10" 15" 20" 25" 30" 35" 40" 45" 50" 55" 60" 65" 70" 75" 80" 85"
Length of Stroke
5 10 15 20 25 30
Time of cutting stroke (secs)

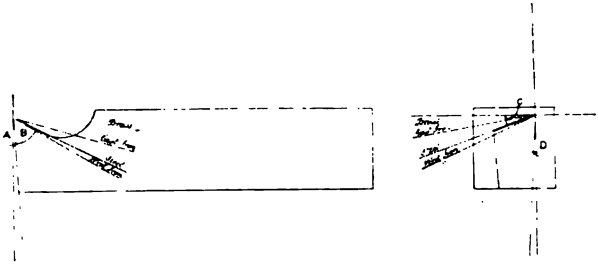
Fig. 4.

Drilling Machines: 1 in. of feed for 200 revolutions up to ½ in. diameter; up to 1¼ in. drill, 1 in. feed to 150 revolutions; above 1¼ in., 1 in. of feed to 100 revolutions.

In some of the larger shops special men are employed, who have nothing else to do but walk round the shop and see that speeds, and feeds, and cuts are kept up to their proper values.

The Correct Grinding of Cutters is at least as important a matter as anything else connected with machine tools. Unless the tools are correctly ground, it is impossible to obtain the best results.

There are three things to be considered in grinding a tool, viz.: the clearance, which is shown at A in the figure; the cutting angle B; and the "lead," which is marked C. Of these A should be as small as possible, so as to just clear the work, not because it has much effect on the cutting, but because the smaller the angle A, the stronger is the tool. If



A is large, there is always the danger that the point of the tool will break off. Turners do not as a rule pay much attention to the size of this angle, but grind it at just about the same angle as the smith cuts it off, and if this happen to be at a considerable angle, the result is that a stiff cut breaks off the point. The correct angle in all cases is about 3 deg. B is the most important angle. The considerations which determine this angle are: (1) The angle which gives the least force of propulsion; (2) the angle which will be most

durable. If the first consideration were only kept in view, the angle which would be given to the tool would be as follows :—

Cast iron, 50 deg.: wrought iron, 50 deg.; steel, 54 deg.; brass, 63 deg.

Less acute angles, however, are more durable, so that in order to secure the best all round results a compromise is effected between the easiest angle and the most durable one, as follows :—

Angle A, in all cases, 3 deg.

Angle B, cast iron, 70 deg.; steel, 60 deg.; wrought iron, 56 deg.; brass, 80 deg.; chilled cast iron or hard gun metal, 85 deg.

Angle C, cast iron, 15 deg.; steel, 20 deg.; wrought iron, 25 deg.; brass, 10 deg.; chilled cast iron or hard gun metal, 5 deg.

Angle D, in all cases, 3 deg.

Angle C will vary to some extent with the cut which is being taken off, but not considerably.

We have already recommended the plan of keeping a special man for the purpose of tool grinding. This plan has many great advantages. A foreman should always insist on a man keeping two or more tools going at one time. One should be ground while the other is in use. If the man has to grind them himself, he will in almost all cases stop his machine, and grind the tool that he has just taken out of the rest, instead of putting in his spare one, in order to keep his machine running while he grinds the other tool. He does this on trade union "principle." If, on the other hand, he has only to take it, or better still, to send it, to the grinder, he has no excuse for wasting his time and the time of the machine in grinding tools, or in talking to other men who may be standing at the grindstone. This latter is a most fruitful cause of loss of time, and is altogether done away with if the men do not grind their own tools. There are special grinding machines on the market, by the aid of which the correct angle can be given without any special

skill on the part of the grinder. The Gisholt Machine Company make a specially useful one, on which all the angles are marked off on graduated wheels. If one of these is not used, the tools should all be ground to gauges giving the angles in the above table.

We have heard men and even employers object to use these speeds and other results on the ground that it is only "theory," that they themselves are "practical men," and that "they have worked at the trade for 25 years, and if they do not know how a tool ought to be ground, then nobody does," &c., &c., *ad nauseam*.

What such people as these call "theory" is simply the result of other people's experience. They themselves have probably never made an *experiment* in their lives, and have, in fact, no more idea what the machine is really capable of than an intelligent apprentice who has been at the lathe for six months. They grind their tools as they used to do 20 years ago, and have done ever since; they run their tools at the same speed as they have done all their lives. They have never tried to run them faster. Their practice is not the outcome of *experience*, but of *custom*, and there is a wide difference between these. A foreman will be met with such statements as these at every turn, and he must be fully prepared to insist on his own orders being obeyed in spite of them. If he cannot do this, he must abandon altogether the hope of getting the best results from the machines. If he has a firm will and plenty of tact, he will be able to carry his point without quarrelling with the men. But however tactful he may be, he will have to part with some of the more obstinate, of the men who are determined to have their own way. Many a foreman has kept a man for years and years quite unnecessarily, being afraid that if he lost him he could never replace him, and when, after some heated argument, he has screwed up his courage and given him the "sack," he has replaced him with a better man in less than a week.

The primary duty of the foreman is to see that the men are

fully supplied with as much work as they can do, and the tools to do it with, without the trouble of finding either themselves, and that they do it properly; that no time is lost from the men not knowing what to do, or how to do it, or from sheer laziness on their part. *Immediately* after a man has finished one job, there must be another ready for him to go on with.

The foreman is a head worker, and not a hand worker. There are many foremen who do not seem to realise that their duty is to superintend, and not to do the work themselves. If there is a bit of "tricky" marking-off to do, a foreman of this type does it himself, while the marker-off stands and looks on. Meanwhile several other men may be waiting for the foreman to come with some instructions, while he does the work of the marker-off. It is the same with any kind of very particular work. The foreman is very anxious that it should be right, so he does it himself, while the men who ought to do it are looking on, though they may be just as competent to do the work as the foreman is, or more so. This is not the part that a foreman ought to play at all. He should not do any of the work himself, but he should so arrange matters that it is properly done by others. In many cases it will be necessary for him to scheme out the way in which it is to be done, but never to do it himself. To do otherwise is simply to put a premium on incompetence and unreliability in the men. His business is to make reliable men out of the material that he has in the shop. He will never do this if he insists on doing all the important pieces of work himself. If he is a very good workman himself, there will be a very great temptation for him to take the work out of the hands of an inferior workman, and to do it himself.

In fact, it is by no means the best workman who makes the best foreman. The difference between the two is that the workman is clever with his hands, and the foreman with his head. The workman has to do things; the foreman has to arrange for their being done, and to see that they are

done properly. He is the man to do the *deciding* in a shop. It is easy enough to spend twice as much time in deciding which way to do a job as would suffice to do it either way. He must be prompt in making up his mind.

The foreman stands in the same relation to the men that the workman does to his tools. The tools that the foreman has to work with are the workmen, and he must know which of those tools to use for any particular job. He must know how to use them so as to produce the cheapest possible result. The measure of his success is seen in the cost book. The measure of the workman's success is seen on the time curves.

Division of Duties.—He has to appoint men for their various duties. He must see that one particular man is told off to do every duty that has to be done in the shop. This is a most important thing to observe, namely, that every single thing that has to be done in the shop must have a man told off to do it, and not a single job must be the duty of more than one man. Let us take an example. One labourer, and one labourer only, must be told off to clear away the cuttings from under the machines. If the shop is too big for one labourer to do it all, then two must be told off; but the machines that each man must attend to must be distinctly defined. If more than one man is responsible for clearing any particular machine, the chances are that that machine will not get done at all, and when the machine-man makes a complaint about it, each will throw the blame on the other. One labourer must be told off to keep the shafting well oiled. If more than one man has charge of this duty, the shafting will never get oiled until it sticks and will not work. One man must be told off to keep the grindstones in proper order, and there should be a definite rule stating at what definite intervals it is to be done, say every Monday, Wednesday, and Friday morning before breakfast. If it is left to the judgment of the man who has to do it, he will leave it alone till it is impossible to grind a tool correctly. It is a job to which men have the greatest

possible objection, and it is not very surprising. There must be a general rule to cover all cases. There must be no doubt about whose duty it is to oil the countershafts. This is the work of a labourer, and not of a machine-man, and if one of them runs hot and seizes, the foreman knows who is to blame. Mending of belts is usually done by the man in charge of the machine, because he has in any case to stand idle till it is repaired, and he might as well be mending the belt as doing nothing. In this way the foreman has to appoint a definite man for every job that there is in the shop, and to divide no duties under any circumstances.

Checking Work.—The next important duty that the foreman has to do is to check over every job that is done in any of the machines, or by any of the fitters under his charge. Before he passes a job as finished he must try all the gauges on, and measure the job over. There are many workmen who would resent this as a reflection on their skill, so he will be well advised if he does this after it has been taken to the stores. At anyrate, wherever he does it, he must never neglect to do it under any circumstances, however reliable the man may be who has done the job.

Very few men who have spoilt a job will come and show the mistake to the foreman, and the result will be that a spoilt job goes through all subsequent stages, when, if the mistake had been discovered in time, all subsequent work on it might have been saved; besides which, if the job, whatever it may be, is one of a number of similar ones, it may be impossible to drop on the man who has made the mistake.

Timekeeping.—The next duty of the foreman to which we shall refer is to watch the time sheet and keep the men up to the mark in the matter of timekeeping. The manager often undertakes this very unpleasant duty, but it is far better to give the foreman undivided control of the men. We have already referred to the conditions of timekeeping, so we shall say no more about it here except to insist that no persistent breaking of the rules should be tolerated from anybody. It is quite a mistake to suppose that any man,

however good he may be, is indispensable, and no question of the sort will arise if it is well understood that everybody has got to keep time, no matter who he may be. Foremen often make exceptions in favour of those abominations known as premium apprentices, who are generally allowed to do pretty much as they like, both as regards timekeeping and in any other respect. This is a very great mistake in the interest of the apprentices themselves, and is also absolutely ruinous to discipline. Many a "premium," as they are contemptuously called in the shops, would turn out a decent workman and respectable engineer if he had to submit to the healthy discipline that other people in the place have to put up with. Instead of which his shop "training" often turns him into an insufferable prig, who is absolutely useless at everything he is put to. In addition to keeping the men up to time, the foreman must take care that no unnecessary waste of time occurs before the men start work when they arrive in a morning or after a meal. When a shop is driven by electro-motors, a self-recording ammeter, when fitted, always shows that up to quarter of an hour after starting work many of the men are not working their machines. The average time lost is about five minutes all round the shop. In a shop of 150 men, at an average of 6d. per hour (including apprentices), this means a cost of 6s. wasted every meal time in wages alone due to this cause.

Engaging and Discharging Men.—The foreman should keep a very sharp look out on the amount of work that there is to be done in the shop, so that he may not at any time be in the painful position of not having any work to give a man to do. His is the duty of regulating the supply of labour to the amount of work there is to do, and *vice versa* to some extent. The foreman must look after this very difficult problem from the master's standpoint. If he is not a master's man rather than a men's man, the sooner he leaves the workshop the better it will be for the master. There is nothing in this to prevent his being a fair-minded man who would not, under any circumstances,

do an injustice to the men. A state of stable equilibrium can only be maintained by everybody's interests being watched, and the foreman is delegated by the master to look after his in the shop, and he fails in his duty if he does not do so. He sees from hour to hour in the stores how much work there is in the shop. When he finds that one particular sort is beginning to run short, he at once takes steps to get a new supply, in ordered work if possible, stock work if not possible. He can see from the blue order sheets what work is on the way; his experience tells him what work there will be to do on it when it comes, and he makes his arrangements accordingly. For instance, if he begins to run short of small turning, he looks among the order sheets to see what there is on the way in that line. He finds all the small engine orders, and sends word into the office that such and such work must be hurried up from the forge. If there are no orders coming on, he sends word round to the office that some stock work of that kind must be put in hand. If the stock of that class of work is already as full as is desirable, the number of men at work must be reduced. If it is found from experience that work of one particular class is always becoming short, it becomes clear that the proportions of the men of the different classes require readjustment, and the foreman must preserve a due proportion between the various classes. Stock is thus a sort of reservoir, the object of which is to neutralise fluctuations in the amount of work to be done. When it gets full, the pipes that supply it are stopped in order to avoid running to waste. It is a most painful duty to begin discharging men when work is slack. At such times a foreman's life is not worth living. He has a shop full of men he knows well and can rely on; many of them he has trained himself, and he knows exactly what they can do. He has got everything into nice running order, and he has to break it all up and start afresh when trade revives.

Short Time.—As far as the interests of the masters themselves are concerned, it is certainly unadvisable to start the

short-time system. By far the better plan is to discharge all that cannot be kept on full time. When the shop is working short time the men scarcely do any work at all that they can possibly avoid. Prime costs run up most alarmingly, and it is practically impossible for the foreman to force matters; so that the best thing to do is undoubtedly to discharge the men, though, as we have said, it is a most painful and difficult thing to do. The principle is exactly the same as is seen when a number of engines are working, and it is required for some reason to reduce the power. The best thing to do in this case is to stop as many of the engines as possible, keeping the others running at full power. Establishment charges and similar things continue, but there is not the waste of steam that there would be if each engine were run at less power.

The *foreman's office*, to which we have already referred in a previous article, should contain every piece of information that can be required about all the jobs in his shop, arranged on such a system that he can at once put his hand on anything that he wants. There is usually more of his time wasted in looking for things that ought to be found at once than in almost anything else. Here, as in the stores, there ought to be a place for everything, and if everything is kept in its place, and an index kept of it, it can be found at once. There can be nothing more simple than marking each paper with a number, putting everything in numerical order in a proper receptacle, and jotting down the number of each paper in a note book. Looking for anything then resolves itself merely into looking through two or three pages of a note book, instead of making a general upheaval of every paper in the office. The time required is a mere fraction of that required in the usual *melée* system to find the paper if it gets lost, which occurs every time it is wanted.

The foreman keeps a complete set of drawings of all the work going on in his shop. These are unmounted blue prints. He returns them to the stores when the job goes out of the shop. He should also keep a strictly private character

book, in which he makes notes as to the character and work, &c., of the various men under him, for future reference, and from which he can draw up reliable testimonials of character when required.

CHAPTER VI.

The Shops.

Modern workshop methods differ from old-fashioned ones chiefly in the amount of common sense and energy that are made use of. There is really nothing mysterious about what are called modern methods. It is not a question of wonderful tools into which pigs are thrown at one end and finished engines taken out at the other, but simply of common sense applied to the processes already used. The guiding principles of the modern systems are—(1) Cultivate orders for standard patterns, and make as many things alike as possible at one time. (2) Provide proper tools in proper order to make them with. (3) Have everything accurate. *Have your drawings correct and complete, and work to them.* Let your draughtsmen do *all* the designing. (4) Work *exactly* to dimensions where parts have to fit together. Let your 2 in. *be* 2 in., and not 1⅞ in. Let your circle *be* a circle, and not a distorted ellipse with a lump on one side. Engage men (or train them) who can be depended on to make things *right*, and have them measured over to see that they are right. (5) Get things done. If a thing has to be ordered, order it at once, and don't wait till the fitter asks for it. Don't procrastinate. Face the difficulties as soon as they arise, and decide at once, and in detail, what is to be done to get over them.

With regard to (1), the question arises how far the whims of customers should be taken into account. These whims are often a most serious nuisance to a manufacturing engineer. The purchaser is often a so-called engineer, who, in virtue

of having spent two or three months in early life in an engineer's shop, considers himself competent to dictate to the manufacturer how things ought to be made, and who, as he is generally spending somebody else's money, will insist on having his own absurd ideas carried out at all costs. Customers of this type are usually as obstinate as they are ignorant, and that is saying a good deal. But if they are not humoured, the order will often go elsewhere; and if they are humoured, the whole arrangements are upset; special forgings of weird shapes have to be ordered and machined one at a time. Shop jigs and templates cannot be used, and the whole thing is a most intolerable nuisance, and it depends on the strength of the firm whether they will put up with it or not. Firms who have made a specialty of engines all their lives ought to know a little more about engines than gentlemen of this type, but this consideration makes no difference to the latter at all. The question is all one of price. What the firm have to decide is not "Is it convenient?" but "Can we make more if we keep to our standard pattern?" or "What extra price are we to put on to compensate us for the waste of time that will be caused by departing from it in this case?" If the firm is a strong one, the price will be so big as to drive away the customer to a weaker establishment, where the manager can afford to be more accommodating, on account of his having fewer calls for standard patterns, and where, in consequence, his methods are less crystallised. If, however, he is accustomed to making things on well-defined lines, a little experience with orders of this character will soon show him (if his cost system is perfect enough) that such orders must have a good price on them if they are to be worth having.

(2) *Tools.*—Unless a shop is provided with proper tools it cannot be a success. No amount of skill and no amount of arrangement and organisation can compensate for the absence of these. We do not mean that in order to succeed a shop should of necessity make a great outlay in all the most modern labour-saving refinements that have been

invented. For a small shop not over-burdened with repetition work, many of these would be worse than useless. But what we do assert emphatically is that all the tools used should be good, strong, and in first-class order, free from makeshifts and temporary repairs. If a tool is too much worn to do accurate work, it should be either repaired at once, without any delay, sold, or put on the scrap heap and a new one got in place of it.

Repairs to Old Tools.—Enormous amounts of money may be wasted in working with worn or inaccurate tools, and no wise manager or foreman will tolerate them for a day longer than absolutely necessary. Attempts to keep them going for rough work are rarely a success. They are put into odd corners, where they take up space, and there is a difficulty in finding them work to do which could not be done more cheaply in the newer tools. As a general rule it does not pay to repair a tool thoroughly. At first sight it would seem that if a tool is only much worn, and nothing else is the matter with it, it can be made as good as new at much less cost than a new one can be bought for. The castings are all there, and only want planing up, machining, lining up, or something else. Such things as leading screws can be put in new, which would have to be new in any case. All this is very nice in theory, but it does not work out that way in practice. The machine is probably an old pattern, one which has long since been replaced by the makers with something very much superior, so that at the best it will always be an old-fashioned and perhaps springy tool, even though it were, for practical purposes, as good as when it was new. This is never the case in reality, however. The repair of a tool is a very much more serious thing than it appears at first sight, and involves a great deal more work. In addition to this, engineers should be able to judge from their own emotions when they get a thorough repair job to do, what will be the feelings (and the charges) of the tool maker to whom they send it. Repair work is always charged for at a much higher rate than new work. This is only natural.

New work is done in quantity, whereas everything is special for a repair job. Special drawings have often to be made. There is only "one off" each of the new forgings or castings. The ordinary jigs and templates cannot be used, and altogether a repair job is a great nuisance in a well-organised place, and is charged for accordingly. On the other hand, new work can be made so rapidly and cheaply, that while a new machine costs very little more than the repairs to an old one, they are enormously more effective and much better value for the money spent on them.

Selection of Tools.—Among the chief points to be observed in selecting tools are that they should be accurate, and enormously stiff and strong. The stiffer they are, the higher the speeds that can be used, and the heavier the cuts that can be taken off with them. Fancy combination tools are no good for an ordinary works. Combination of lathes and shaping machines and the like monstrosities should be eschewed. The attachment for the extra purpose increases the price, diminishes the proper efficiency of the tool, and is never used. Plain work only requires plain machines. A screw-cutting gear is no earthly use on a machine that is always used for turning shafting, connecting rods, or crank shafts. If the extra money that this costs is spent in increasing the strength of the bed, the headstocks, and the tool rest, it is used to very much better purpose.

Multiplication of Cutters.—All tools should be considered as to whether they will allow of more than one cutter to work on the job at the same time. This is a very important point. It should be the constant endeavour of the manager or foreman to get two, three, or four tools on the job at the same time if possible. The more he can get at work the quicker his work will be done, unless the tools take more time to rig up than the time that is saved by increasing the number of cutters. A planing machine has to go backwards and forwards whether one, two, or three, or more cutters are at work removing metal, and provided the driving power is great enough to stand it, every stroke that the table makes

when two cutters are at work is worth two strokes when only one is there. The higher the belt speed the less likely will it be to slip when the machine is doing extra heavy work. The quick return should not be too quick, otherwise the machine will shake itself to bits and create a deafening rattle in the process. If a large machine, it should be provided with a gear for winding the cross slide up and down. This process occupies a huge time if, as usual, it has to be done by hand. Care should also be taken that the feeds provided are broad, and that there is enough power to drive them. There are multitudes of machines, especially lathes, on which a workman cannot use a broad feed, because the belt which drives it will not stay on the pulley.

Special Tools.—It is not our intention to describe the special tools that should be found in a well-equipped works. In a general shop, doing general work, it is very difficult to devise many special tools that will be frequently used enough to warrant their being made. The special tools that would be extremely useful for engine work would in most cases be entirely useless for, say, hydraulic work or machine-tool work. Special appliances and fittings can only be profitably employed when the cost of them can be saved in a reasonable time in wages. If a special fitting costing £5 is only used once a year, which when it is used will save a man half a day's work, it cannot be said to be a profitable investment. On the other hand, if it were used once a week, it might be a most valuable thing to have. The same considerations must be taken into account in deciding whether it is advisable to invest in such a thing as a capstan lathe. These machines will turn out small articles, such as crosshead bolts and the like, in enormous quantities, all exactly alike, at a fraction of the cost at which they can be made by the ordinary process. The question is, What will it cost and what will it save in a year? Both these questions can be very easily answered. Most employers (in this country at anyrate) ask themselves the first one only. The over-sanguine ones ask the second one only, and not

always that in a calculating sense. The result is, that if the machine is bought, perhaps it eats up all the work there is for it, and then stands idle because there is nothing for it to do. On the other hand, there are tools and fittings, often of modern introduction, that are in constant use in all kinds of work, which cost money and save an immense amount of time, but which can be dispensed with. This is the kind of outlay that should never be stinted by a firm wishing to cheapen production. Take, as an instance, a tapping attachment to a drilling machine. Who has not seen two or three fitters spending a whole day or more in walking round a tap with a long wrench, when the same work could have been done in half an hour in a properly-fitted machine. Now, tapping is a process that is done every day, yet there are many employers who would go off their heads if their foreman suggested getting a machine to do the work, or having an existing drill fitted with the attachment. Or, again, consider the clumsy process adopted in many shops in boring and turning a pulley. It is chucked, bored, and then stuck on a mandrel (which more often than not has to be specially turned for the process), then turned on the outside, and so on, when a very small outlay would enable the two operations to be performed simultaneously. But before even such an outlay as this is made the management should consider whether the apparatus will be used for isolated pulleys, and, if so, whether the time saved in the actual machining of the pulley will be lost, or more than lost, in rigging up the attachment on the machine. Many shops have only one dog chuck for several lathes, which are all constantly using it. In fact, the attitude of most masters seems to be, "How can I get the work done with the least plant?" (a very laudable aim as far as it goes) without any thought of the question, "How can I get it done at the least expense?" These people regard any outlay for machine tools as a dead expenditure that will never be recovered, and therefore to be put off as long as possible; whereas the proper way to regard it is as a certain sum of money put

down now in order to avoid having to pay several times as much in the next ten years in wages. The old machines have already paid for themselves, probably several times over, so that it is no great loss if they are now put on one side to make way for new ones. With regard to new tools, the attitude of most masters is, "I can't afford it"; whereas, if they studied their real interests, it would be, "I cannot afford the luxury of doing my work with old tools like this; it costs too much in wages." We see here the same phenomenon that we have alluded to before. People of this kind have not got enough imagination. They see the balance at the bank easily, but it is not so easy to see money dribbling away as wages. They cannot see or imagine this loss capitalised, otherwise there would be less difficulty in inducing them to be more enterprising with the outlay for plant.

Occasional splashes of extravagance in this direction, however, must not be mistaken for enterprise. It is a very easy thing to waste in tools a lot of good money that will never be recovered in wages saved. Before any outlay in this direction is made, the buyer ought to be well assured that not only is the tool a good one in itself, but also that it is suitable for the class of work that is done in the shop. This is particularly the case with such things as milling machines. Now, a milling machine in its own place is a very useful tool. It can do work that no other tool can do, and it can also do work that other machines can do in a fraction of the time that other machines can, and in some classes of repetition work it is absolutely indispensable.

But there are a great many jobs at which a milling machine cannot hold a candle to a slotting or a shaping machine. We are aware that it is rank heresy to say so, but according to our experience a good deal of the ordinary engine work often done in a milling machine is of the latter class. Milling such things as connecting rods leaves a nice finish, but in point of accuracy and in point of rapidity it is not to be compared with a slotting machine for this

purpose. We say this from experience, having made a large number of accurate time trials on the two machines. At anyrate, if milling machines are used, they must be very well supplied with cutters, and a cutter grinder must also form part of the outfit. Without this a milling machine, if not absolutely useless, is not far from it. It is indeed in the small things that a judicious liberality is most required. In general no fancy tools are necessary, so long as the ordinary tools are strong, in good condition, and thoroughly well supplied with accessories. In most small shops they are neither the one nor the other.

Where, for instance, can one find a small shop in which are to be found such things as eccentric chucks, monitor chucks, ball turning rests, adjustable packing blocks, or even anything but the crudest device for cutter heads of boring bars, and the thousand and one other things which, though they are quite inexpensive, make the difference between expensive and cheap work?

Grinding Machines.—This is a form of machine which does not receive nearly as much attention as it deserves. Grinding can be profitably employed in conjunction with lathes or planing machines, either for finishing only or for roughing out. It is most profitably used in finishing only. It leaves an excellent and very accurate finish on turned work, internal as well as external. Some up-to-date firms finish all plain turned work exclusively by grinding. The article is roughed out to near the finished size in an ordinary lathe, and is finished off in the grinding lathe, in which a rapidly-rotating emery or corundum wheel, running at a peripheral speed of 3,000 ft. to 5,000 ft. per minute, is substituted for the tool.

Power of Machines.—In addition to strength and rigidity, care should also be taken that the belts are strong enough and their speeds great enough to take off a good stiff cut. Nothing is more annoying than to find a machine that is stiff enough, but will not stand up to a heavy cut because of the belt slipping or breaking. Old machines are especially

noticeable for this feature, and that, if nothing else, should be enough to convince anyone that it is not worth the money to attempt to repair a machine of this type.

A lathe for ordinary shop use absorbs about a horse power. The stress in a belt should not be more than about 45 lb. per inch of width, so that its speed in feet per minute ought to be at least $\frac{33{,}000}{45 \times \text{width}}$. Thus a 3 in. belt will move, when on the smallest countershaft pulley, at not less than 250 ft. per minute. A still higher velocity is preferable.

Another point to observe is that the pulleys are not too much "bellied." If they are, the belt will only touch the pulley in the middle, and not at all at the sides; the belt will therefore slip. For ordinary machine belts $\frac{1}{16}$ in. convexity should be the very maximum.

Making Small Tools.—Generally speaking, it is a great mistake to make in the works small tools such as taps, reamers, and similar things. They can almost invariably be bought for 50 per cent less from firms who make a specialty of that kind of business than they can be made for at home, and in addition the article when bought is very much superior to what can be made in an ordinary works. Accurate observation of costs will almost invariably show this, but most engineers seem to cherish the conviction that they are saving something if they make such things themselves, whereas they are, in fact, simply wasting money on an inferior article.

Among the things which every firm should possess, but which very few do, are a set of hardened and ground steel mandrels, made to standard sizes, and kept, like all other tools, in the stores. The general custom is, when a man wants a mandrel for any purpose, he hunts about under benches and lathes till he finds a piece of round iron which is slightly larger than he wants, and after wasting considerable time looking for it, he tries whether there is a place on it which will fit his job. Of course, there is not; or, if

there is, he finds on putting it in the lathe, that it does not run true just there, and he has to turn another place up to fit. When eventually he gets the job done, he has spent as much or more time looking for the mandrel and trueing it up than he has on the rest of the job. This occurs every time a mandrel is used, and the total waste of money due to it in a year would probably buy several sets of properly made and hardened "arbors." If the mandrels are made exactly to gauge size, and the work is also made exactly to gauge, the one will always fit the other, although if the job to be turned is of a rather large diameter it may be necessary to use special means other than the tight fit for holding it on. Expanding mandrels are often extremely useful if great accuracy is not required.

Jigs, Templates, and Gauges.—An important feature of modern workshop methods is the great use which is made of jigs, templates, and gauges.

Of course a jig can only be profitably employed when many articles all alike have to be made. When the design is changed the jigs as a general rule become useless, and this is the chief reason why it is necessary to keep to one design. A jig is really a device for mechanically setting and holding the work in the machine, and the accuracy with which it does this is dependent on the accuracy with which the jig itself is made, and the accuracy with which the previous jobs have been done on the work. V blocks, for instance, are a sort of jig, and the accuracy with which a round bar is set by means of them, parallel to a surface on which the V blocks rest, depends on the exact similarity of the two V blocks, and on the roundness and uniformity of the rod.

Jigs can be made for all sorts of purposes. In fact, wherever a job has to be set it is almost always possible to make a jig that will do the work. Jigs cost money to make, and in order to determine whether it is worth while to make one for any purpose it is necessary to find by observation how long it takes a man to set the job, estimate how many times he has to do it in a year, estimate how much time it

would save him if he had to merely bolt it in the jig, and calculate the price that the jig would cost to make. It is then a simple sum in arithmetic, the data depending on the firm's ideas of a profitable investment. It is clear that the more things alike that have to be made in the jig in a year the more profitable will the investment be.

The only kind of jig that most shops are acquainted with is a plate which is used for drilling holes without marking them out, and even that is considered too expensive to make. Every jig that is made for shop use has a number, and a complete set of drawings of them all are in the drawing-office. As far as possible the draughtsmen design the work to suit the jigs already in existence, and the number of the jig to be used is marked on the drawing, so that the workman has merely to ask for the jig of that number from the stores, and return it to the stores when it is done with.

Jigs can not only be used in connection with machine work, but are often also extremely useful in vice work—in fitting connecting rods, for instance.

Templates.—Templates are used as much as possible for marking work off. They are much cheaper to make than jigs, but are, as a rule, not nearly so profitable an investment.

Gauges.—When any piece of work requires to be finished accurately, but which is larger than any of the standard shop gauges, hardened steel bar gauges are used, or home-made hardened caliper gauges. These can usually be made and hardened in the works.

Tool Fitters.—Except in very small works, it is well worth while to keep one or more very good workmen as tool fitters. In a works of moderate size there is usually enough work of this class to keep a first-rate mechanic and a helper fully employed on making gauge tools, jigs, and other things. He can always be put on some other work when he runs short of tool work. If he is an ingenious man, who has kept his eyes open, he will be worth four times his wages.

3. Completeness and Accuracy of Drawings.

3. It would be difficult to overstate the importance of making the drawings not only accurate, but complete. In dealing with the drawing office we have already pointed out the need of absolute accuracy in the drawing. Few engineers would dispute this. The need of very full dimensioning is not, however, so apparent. Many engineers will say that if all the important dimensions are inserted, the others can just as well be determined by the workman, who is quite as competent to do it as the draughtsman, and (they will add) often much more so. This is a position with which we cannot agree. In our opinion, the dimensions put on a drawing ought to be such that if they are followed they should absolutely determine the size and shape of every part of the work, and the workman should be instructed that under no circumstances should he determine any dimensions for himself, either by scaling the drawing, or otherwise, and that if it is ever found necessary to scale a drawing it must be sent up into the drawing office. Indeed, in some works all drawings are put into glass cases, both to prevent them getting dirty and to prevent the workman from laying a rule on them. Of course, a fully dimensioned drawing takes more time to make than one in which only a few leading dimensions are inserted. The full dimensioning of a drawing requires not only much time and care, but also much experience on the part of the draughtsman. In spite of this, and of the fact that a machine made from an undimensioned drawing may be just as good as if the drawing had been complete, there can be no doubt that it saves time and expense in the long run to have the dimensions on a drawing as complete as they can possibly be made. It must not be forgotten that at some time or another during the manufacture of an article every single dimension of whatever kind must be determined by somebody or other. Now, the draughtsman is at work determining dimensions the whole day long, and he can therefore do it very much

more quickly than the workman. Not only so, but every dimension that the latter has to fix on involves taking him away from one job, viz., making the article, and putting him on another, viz., designing it (for that is what it practically amounts to). The very essence of good works management consists in keeping each man to his own job and making the various jobs fit in with one another. This will, in the long run, produce the most economical results. It is often said that the draughtsman has too much to do to put in all the dimensions that are required if this principle is fully carried out. If that is so—*i.e.*, if draughtsmen have to be continually sending drawings into the works not fully dimensioned, because some other drawing is wanted at once—it is the clearest indication that the drawing office is undermanned, as is, in fact, the case in perhaps the great majority of engineering works. A draughtsman is a man who has never got a clear conscience, and the reason of it, and, it may be added, the prime cause of the heavy doctor's bill which is incurred in many works owing to drawing-office mistakes, is the ever fatal uncalculating "economy" on the part of the management. By knocking £2 a week off drawing-office wages, which they *can* see, because it is such a considerable proportion of the whole drawing-office wage bill, they perhaps put £10 on to the shop wages, which they *cannot* see, because it is such a small proportion of the whole workmen's wage bill! There are a great many engineers who are constantly indulging in sneers at the expense of the draughtsmen in general (and probably with more or less justice), but they may, with more justice, direct their gibes against the general stupidity of managers and proprietors, for the real cause of the general inefficiency of the drawing office is that it is generally understaffed, and that the wages paid do not make the highly-responsible position of draughtsman one which an able man cares to fill as a permanency. If engineers generally were prepared to pay for the services of able men in the drawing office, there would be no lack of able men to fill the posts.

Again, it is of the highest importance that the drawing office should know exactly, and not approximately, the size of every part of any machine ever made by the firm. Now, unless every drawing is exactly to scale, and every workman's rule is correct, they cannot possibly know this without every dimension being inserted in figures. If the practice is adhered to of returning drawings to the office when missing dimensions are discovered, it ensures that all drrawings shall correspond, and that the staff will be especially careful to make them complete in the first instance.

4. Accuracy of Work.

Advantages of Standard Sizes.—If there is one thing more than another that is imperatively necessary to secure economy of work, it is that everything should be made to standard sizes. Well-made modern machine tools are instruments of great accuracy, and if they are worked by competent men, they can be made to turn out extremely accurate work. Of course, it takes slightly longer to make a shaft *exactly* 2 in. diameter than it does to make it *about* 2 in. diameter. It would therefore seem at first sight that it would be cheaper in the same proportion to make an engine without being very particular about the exact accuracy of all the dimensions, because as far as the working of the engine is concerned it does not make any difference whether the crosshead pin, for instance, is 2 in. or $1\frac{31}{32}$ in. diameter, as long as the journal is the same. The trouble comes in when the pin is $1\frac{31}{32}$ in., and the hole into which it has to fit is 2 in. But this is not the whole trouble—far from it. Suppose the manager comes into the shop one day, after receiving a sharp letter from one of his customers with regard to the non-delivery of an engine which was promised two months ago, in order to see how it is getting on. He sees the piston casting lying by the side of a lathe, and the turner "cleaning his lathe," or doing something else of

equal importance, and the following dialogue ensues between him and the foreman :—

Manager: "Why haven't you got this piston in the machine?"

Foreman: "I can't put it in yet, because Bill Jones hasn't got the piston rod done to bore it to."

Manager: "Why hasn't he? It is a much more important job than that thing he is doing now."

Foreman: "Well, he hasn't got the gland to turn it to yet."

Manager: "Well, why isn't that done?"

Foreman: "Because Jack Robinson hasn't bored the stuffing box out, and we can't turn the gland till we know what size the stuffing box is going to be."

Manager: "Why isn't the stuffing box done?"

Foreman: "Well, we can't finish that till Harry Brown gets the check hole bored in the bed-plate flange."

Manager: "Why, Harry Brown had that bed plate on three days ago; I saw it on the machine myself. Why isn't it done?"

Foreman: "Well, the belt is broken, and there isn't a bit of 3 in. belt in the stores to mend it with."

(Exit manager, to send out a labourer to see if he can pick up a bit of 3 in. belt at a second-hand machinery stores.)

This kind of thing is bound to go on to a greater or less extent in any place when the system is pursued of making one part of an engine to fit some part of the same engine that is to work with it. In a modern workshop all these parts would have been made on the "interchangeable system," so that Bill Jones and Harry Brown, and the other men, would have made their respective parts to fit standard gauges quite independently of one another, with the perfect assurance that they would fit all right when they were brought together.

The Interchangeable System.—The principle of what is called the interchangeable system is old Euclid's first axiom (which ought also to be the first axiom of every engineer in

the world), "Things which are equal to the same thing are equal to one another." Translated into the language of the workshop, this is, "If a plug gauge fits a collar gauge and a gland, and if a *round* (not oval) spindle fits the collar gauge, then the gland will not only slide on, but will fit on the spindle."

This is a very simple thing, but it is astonishing what a lot of learning it seems to take. The truth is that old-fashioned engineers, owing to their attachment to antediluvian tools, have got so much into the habit of calling $1\frac{31}{32}$ in. "two inches," oval "round," and skew-shaped "flat," that they have come to distrust that axiom of Euclid's, and to think that it needs to be rectified with a scraper.

Gauges.—Of course, in order that the "interchangeable system" may be carried out, the first requisite after the accuracy of the tools has been ensured is to have a set of reliable hardened and accurately-ground steel gauges, and this is precisely what the old-fashioned engineer will not buy. "This firm has been carried on for 50 years without wasting money on fancy toys like that, and we are not going to begin now. If you want any gauges, get some bits of cast iron and bore them out yourself." As a matter of fact, a set of gauges is as much a necessity in a modern shop as a steel rule is. Every man who is doing a job that has to fit another job must be provided with the forging or casting, the drawing, and the gauges. It is impossible to set a pair of calipers to a steel rule with anything approaching real accuracy. Even if it were, many of the rules used by the men will be found to be very inaccurate. Many firms keep one set of gauges as a standard, and another for workshop use. It is imperative that the gauges should be absolutely correct. If the collar is slightly larger than the plug, a good workman can make a spindle which will go into the collar, and a ring that will slide on the plug, yet the ring will not go on the spindle. The two must be so nearly alike that a good workman cannot split the difference.

There are many jobs where ring and plug gauges cannot be used. In these cases caliper gauges, hardened and ground exactly to size, must be supplied. Great care must be taken of all these gauges. For instance, they must not be tried on when the job is running, or they will speedily be destroyed, and they must be returned to the stores the moment they are done with. The foreman should keep a good micrometer caliper to check them occasionally. Nobody but the foreman should be allowed to touch this latter.

The Marker-off.—Before any work of any sort is done on a casting or forging, it is first necessary to ensure that it will "hold up" to drawing dimensions. This must be done before it goes to the machine. As soon as possible after it has been weighed it is taken to the "marker-off" at the large face plate, to be examined, measured over, and marked off. There must literally be no exception to this rule.

Unfortunately, however, it is a comparatively rare thing to find a face plate in a small shop large enough to take the larger castings. That is another of those "useless toys" for which many engineers have such a contempt. All pieces, large and small, go through the same process, namely, examination by the marker-off, to ascertain if they are sound, and to pick out the lumps of "bomantique" that may have been filled into the blow holes by the astute founder, and to ensure that the casting will "hold up" to drawing size. This latter is usually left to the machine-man to whom the job is given. This is wrong, for the following reason, that if he discovers a mistake in one of the pieces, it has often to go back to the forge or foundry to be rectified. This upsets the arrangements entirely. He has adjusted his lathe or other machine for the work, and when he does the job he has to work one short, and when the defective piece comes back, to waste all the work necessary to get his machine again adjusted. Besides this, if several forges or foundries have been at work on the same job, it may be impossible to find which of them has

made the mistake, especially if the discovery is not made till a considerable time after the piece has been delivered, and, in consequence, the home firm has to pay for the alteration, which expense ought to fall on the firm who made the mistake. If the mistake has been made either in the pattern shop or by the drawing office, it ought to be brought to light at the earliest possible moment, so as to save any work being wasted on a blunder. Then, again, if the job is rather pushed, it hinders things terribly for a mistake to be discovered at a late stage of the work. By a little extra pushing a job may often be got out to time, if the pushing can be spread over a month; whereas if it has all to be crowded into a week, the chances are that it cannot be done.

The proper person, then, to go over all castings, as soon after they arrive as possible, is the marker-off. He has appliances for centering all the lathe work, and making sure that it will "hold up" in every part. No casting or forging is to be considered as accepted until the marker-off has run his lines through it. He also marks off all the big work, and measures it over and reports any error to the foreman, who immediately sends for the head draughtsman. This face plate should be made absolutely rigid and level, and as conveniently placed as possible. If it has a special crane to itself, all the better. It will often be very useful for hanging a plumb line to. If it is provided with a large perpendicular plate along one side, it is much more convenient than a bare surface plate alone. It should be provided with a large rigid scribing block, and plenty of good steel straightedges, 6 ft. or 8 ft. long, large squares, and other tackle. When a job is given to a man to do, he should almost always have a line or lines on it to set it to. Plenty of planers are very good mechanically, but exceedingly poor geometrically. The marker-off should do the necessary geometry for them, just as the draughtsman does the necessary calculations. All the instructions the planer needs are, "Plane down to that line." The ancient method is to give the casting in its virgin state to the planer, who perhaps gets one flange

planed down before he finds that some other flange will not hold up to that surface so as to be true, and if by some rare piece of good luck the flange will stand another cut over it, it is "thrown" a bit, and another half day is lost. But if the flange is already as thin as the drawing, or thinner, either the job has to be sent out a "botch," or the casting scrapped. The proprietor or manager is by no means informed of these goings on. "Planing, x hours," is all he sees of the transaction. x hours may be a fit and proper time for such a job for all he knows to the contrary, and the foreman, and still less the planer himself, is not likely to enlighten him.

Giving Out of Jobs.—When the job is marked off, the foreman gives it to the machine-man, along with the drawing and any necessary templates or gauges. Before doing so he looks up the time curves to see what time the job ought to take, enters the giving out of the job, and notes in his own mind and in the Time Work Book when it ought to be finished. He also enters the job on the time sheet of the man concerned, describing it fully, as already explained in connection with the time sheets. Then he has to determine how the job is to be done. He must be able to see through the job from beginning to end. He should never lazily give a man a job without having a clear idea in his own mind what is going to be done with it. For instance, if it is a planing job, which will have to be subsequently bored, he must be able to see, in imagination, how the borer will set his bar, and all other particulars right through to the finish. He will then be able to judge as to the best order in which the job should be taken to the various machines. In some cases a very difficult job would be made very much easier by merely reversing the order in which it is done. This is why it is of such vital importance that a foreman should himself be a good machinist; not because he has ever to tend a machine himself, but because it falls on him to determine the best way of putting a job in hand. He cannot do this unless he is an expert himself.

In the case of small jobs the foreman sees that the workman is provided with drawings and gauges for every fitting part. In all cases the man must regard himself as working simply for stores. He has no concern with the fact that he is actually turning a job for the 7 by 6 engines. As far as he is concerned, that job has to be made to the gauges and the drawing, and then sent to the stores. The foreman there measures it over, tries in all the gauges, and, if they are all right, the job is greased over by the stores labourer, and put in its proper compartment, ready for the next machine-man or the erector, as the case may be, and the foreman fills up the time records in the books and on the man's sheet.

Big firms who make a large number of standard-size engines have often two kinds of stores—the manufactured stores, wherein are kept the finished parts ready for the erectors, and the unmanufactured stores, wherein are the parts in the various stages of manufacture. With firms of this kind the execution of an order merely resolves itself into specifying to the storekeeper the sizes of the various articles which are to be sent to the erecting shop, with an order to the erector to put them together. The parts are all alike, and it is a matter of perfect indifference which is selected.

Blunders.—Of course, in these cases, if a man makes a mistake, by making a piston rod too small, for instance, it means wasting the part, as the disorganisation and trouble consequent on making a special set of parts to suit the blunder is not to be thought of. Even in a small works a blunder of this kind ought to be regarded as a most serious offence, and it is often a question whether it would not be economical to throw away the part, rather than send away a botched-up job. In addition to the nuisance of giving special instructions, and the delay that will be caused by the impossibility of using the ordinary gauges and methods, there is also to be considered the fact that if at any future time repairs are required for this engine, the new parts cannot be made simply to the drawings, and unless the error

is described accurately in the Record Book, there will be danger of a mistake. This possibility, however, is but a trifle compared to the demoralising effect such proceedings will have on the men. If a man comes to think that a mistake of this kind can be rectified by making other parts to suit, he will not be as much impressed as he ought to be with the necessity of making things absolutely right. If a man cannot be relied on to make a job just right every time, he is not a fit man to employ in a first-class place. Such a man is not worth keeping even at reduced wages. He is like a worn-out machine tool in that respect. It will be always difficult to find him in jobs that do not require skill. An apprentice at one-third of his wages can always do jobs that do not require skill. If a man is paid less than the standard wages, it will make him dissatisfied; and if he is of a revengeful disposition, he will sometimes deliberately spoil something valuable when he intends to leave.

But, of course, accuracy and fine work can be carried to extremes. It is only in the fitting parts where this exact accuracy is desirable. To spend a lot of time in machining with great accuracy parts that do not fit any other part is as bad as it is not to do so when there is necessity for it. It is simply time and money wasted. Calipers are quite good enough in cases where parts have not to fit together. Here it may not be out of place to enter a protest against the horrible process of finishing accurate turned work on the lathe with a file. A job is invariably untrue when finished in this way. It makes the article operated on both not round and untrue with the centres. An expert workman can finish a job with a tool with as great accuracy as is necessary, or if a fine polish is required, it can be secured by means of a lead lap, which is infinitely preferable to a file, because an accurate finish and perfect polish can be left without destroying the roundness of the work, though even this has a tendency to make the job slightly out of truth with the centres. The best form for a lead lap consists of a pair of lead bearings bored out and fixed in an iron clamp, and fed with emery and oil.

The importance of keeping things to standard sizes is seen also in the case of such things as drills. Most small shops are, as we have before remarked, very scantily supplied with drills. Even those that are found are deprived of two-thirds of their utility owing to the variations of size that are found. Any drill may be made to fit almost any drilling machine in the shop if only a proper set of sockets are made for each machine. The shank of the drills ought to be made in as few sizes as possible, so that each machine has not to keep a large number of sockets. Plenty of twist drills ought to be supplied. These drills when properly ground can do extremely accurate work, and can do it much more rapidly than the ordinary flat drill. Machines for grinding them are on the market, but a good man can grind them by hand as well as they can be ground by any machine. If they are accurately ground, they will drill a hole so true that when the drill is taken out of the hole that it has itself made, and the metal has been allowed to cool, the drill cannot be put back into the hole, owing to the contraction.

The Men.—It is almost unnecessary to say that the main object to be kept in view in engaging men is to get the most good work done per pound of wages paid, and not, as many employers seem to think, to fill the shop with men whose wages are all as much below a certain maximum as possible. Provided that wages are determined according to a reasonable principle, and not by mere caprice (as is so often the case), it is very much to a firm's interest that individual wages should be as *high* as possible. As has been before remarked, the foreman should have sole charge of engaging men, and should be empowered to dismiss old ones at his absolute discretion. The firm can then hold him responsible for maintaining a good proportion between the amount of wages paid and the amount of work turned out, but they certainly cannot do so if they insist on engaging the men themselves, keeping on men that the foreman feels he could do better without, and sacking men that he wants. If the foreman is not sufficiently reliable to engage and discharge men, he is not fit

to be foreman. It is absurd that the firm should expect to manage the shop themselves, and then profess to hold the unfortunate foreman responsible for their own mistakes. When a foreman takes a man on he gives notice of the fact to the timekeeper, who takes his address, and assigns him any check number that may be vacant, and fills in some such form as the following, which is sent into the office to be posted to the man's last employers. On the back of this form is printed the name of the home firm, so that the form can be returned to them by merely folding it up. Some firms stamp the forms, so that they can be returned post free.

CHARACTER FORM.

Tutbury Ironworks,
Tutbury,
.....189...

Messrs.....

.....

PRIVATE AND CONFIDENTIAL.

GENTLEMEN,

A man giving the name of.....of.....has applied for employment at these works, stating that he has been recently employed by you. Would you kindly oblige us by filling in the particulars set out below as to his character and ability, and returning this form to us at your earliest convenience?

In what capacity employed? .....
Date engaged .....
Date left .....
Cause of leaving .....
Is he sober? .....
Industrious? .....
What are his capabilities as a workman? .....
Is he a good timekeeper? .....
Rate of wages .....
Further particulars of character .....

We are, gentlemen,
Yours faithfully,
BROWN AND CO.
per.....

When a man is engaged, it is to be understood that it is subject to his reference and a week's trial proving satisfactory. His rate of wages can be fixed by the foreman after seeing what are his capabilities. To do this he will give him two or three well-defined jobs about which he has full particulars in the books, and note very carefully his performance on them, making allowances for the fact that he is new to the work. He should take care that he does not fix the wages too high to begin with, or raise them prematurely. It is always easier to raise wages than to lower them. A man whose wages have been reduced is a very undesirable man to have on the premises. He will generally work without any energy, even if he does not wilfully waste his time. It is usually better to get rid of a man than to "cut off his tail," as the process is called. Some kinds of men, if they knew that their wages were being reduced because the amount of work they turned out was smaller than that of others, would work with all the greater energy in order to redeem their position. With the majority of men this is not the case. They simply sulk, and wilfully reduce still further the amount of work they do. They keep their job only till they can get another one, and in the meanwhile do as little work as they dare. They also talk about their grievance among other men, and do their best to spread disaffection. Before sacking a man for his slowness, a foreman should be continually warning him that his work is not so cheap as that of other men, so as to give him a chance to do his best. It is most convenient to give or require an hour's notice only when a man leaves.

Cheap Hands.—Time observations will disclose with the greatest possible clearness that the worst and most extravagant policy that a firm can adopt is to employ men at low wages. We are not by any means advocating a system of paying men more wages than is necessary, nor are we advocating good wages on theoretical principles, but because we know from experience and careful observation that the dearest men that can be put into a works are the men who

will accept low wages. There is not one exception in a thousand to the rule that a good workman will not do so, because he knows perfectly well that he can get better pay whenever he chooses to try. The best workmen are invariably the cheapest, and the best workmen can only be secured by paying the best wages.

The following is a fairly representative example of many similar observations made by the author. Turning: Man A, at wages £2 per week, time occupied 37 hours; man B, wages 38s., precisely the same job, 44 hours; man C, at 38s., 48½ hours. The jobs were exactly alike in the three cases. We are not professing to draw deductions as to the relative values of the three men from the one observation. Similar discrepancies were seen in every case, and always much in favour of the man at the high wages. Taking the above figures as they stand, it will be seen that if B was worth 38s., A was worth about £2 5s., so that he was on this basis about 5s. per week the cheaper man; if C were worth 38s., then A was worth nearly £2 10s. These figures represent wages alone; they do not take count of the greater productiveness of the machine in the hands of the better man; that alone is a serious consideration.

Another example. Planing: D, at 38s., time occupied 22 hours; E, at 30s., 36 hours. Thus, if E were worth 30s., D was worth 49s.; in other words, at 38s. he was about 11s. the cheaper man.

We could quote many other instances of the same thing. We are not asking engineers to take this principle on trust, but to make observations of their own.

It is the easiest thing in the world for the veriest novice to tell a good workman from a bad one by merely measuring up their work with a micrometer, and looking at the time curves. A good workman for practical purposes is one who turns out accurate work, with a good finish on it, in a relatively short time. He does not need to have the very smallest knowledge of theory, or of anything outside his own trade, although a good workman usually has. It is

impossible to distinguish him by the length of time he has been in the trade. There is many an apprentice of five years' standing who is a better man than a man who has been at it for twenty years. He cannot be recognised by what he used to do (according to his own account) at his last shop, not even with certainty by the way he goes to work (though a shrewd foreman can form a pretty accurate estimate of him by watching him manipulate his tools). The final and ultimate criteria are the micrometer caliper and the position of his points on the time curve. "By their fruits shall ye know them." A man who is careful enough to turn out accurate work does not make big blunders. Accurate work is not produced by accident, but by care. Many small proprietors would be up in arms in a moment if they discovered a foreman was paying a first-class man a very high wage, even though he could show conclusively that the man was turning out much cheaper work than the man at a low wage. They would rather lose him than continue to pay *one man* such a wage as that. As a matter of fact, in this case it ought not to be regarded as a high wage, and the firm have no reasonable ground of complaint so long as the amount of work turned out per pound of wages is satisfactory. Of course, it is quite another matter if the foreman is found paying his favourites higher wages than they are worth. If he is the sort of man to do this, the sooner he and the firm part company the better it will be for the latter. The manager should mercilessly stamp out any cliquishness that he finds with the least possible delay, and in the most effective manner, whether it arises from trade unionism or any other cause. It will frequently happen that a man is exceedingly good at one job, but comparatively poor at another, and it rests with the foreman to use his powers of judgment and observation to get each man to his right job. One man will be very good at rough, heavy work, who can pile up thick cuttings at an enormous rate, but who is rather slow and clumsy at a small, fine job; and the man who is expert at the fine job will be similarly useless when it comes

to fetching off the stuff. Strange to say, it does not always happen that the man is best at what he has been accustomed to. It should, in fact, not matter a straw to the foreman what has been a man's past experience, or whether he has served an apprenticeship, so long as he can do the work correctly and in reasonable time. As we have said, the criteria of his value are the micrometer caliper, and the time curve. It may be said that the remedy for all these ills is the introduction of a system of piece work. It is often impossible to do this in a small works, where there is not much repetition work.

Rules and Regulations.—The fewer of these that are made the better it will be for everybody concerned. It is not the least use to post up a long list of rules to regulate the men's conduct: firstly, because nobody ever reads them except for the purpose of jeering at them; and secondly, because the men know perfectly well how they are expected to behave themselves, without any elaborate rules. If a man has not common sense enough to behave himself without annoying other men, the sooner he gets the "push" the better. It brings the whole management into ridicule to post up a new iradé every five minutes about every irregularity that is discovered. If it is considered necessary to specify exactly the rules that must be observed with regard to such things as time and returning things to the stores, &c., they ought to be printed, and a copy given to every man when he is taken on. But nothing should be propounded as a rule unless it has first been perfectly tested and is to be strictly adhered to.

Breaking into Jobs.—It is most important to notice the very prejudical effect of breaking a man off a job (whatsoever it be) until he has finished it. It is for this reason that machines can be made in quantity so much cheaper than they can be made singly. Observation will generally show that a man can do about four things alike in succession in the same time as he can do three of the same things singly. Of course this will be partly accounted for by the

fact that he has to adjust his machine; then, doing several things all alike, one adjustment will serve for the whole of the things which are done at one time. Then there is the walking about and collection of tools and other preliminaries to arrange. But all these things together do not account for the great difference which time observations will invariably disclose. A man seems to get somehow into the spirit of a job and to know how to tackle it when he has had several of the same things just before. If he is interrupted in the middle of it the spell seems to be broken, even though he has not to alter his machine in any respect. It is difficult to account for this, but the author has observed it over and over again, and has no doubt that others have done the same.

For instance, the following figures represent the time to do four pieces of planing, all exactly alike, one following immediately after the other—35, 27, 23, and 24 hours. On two subsequent occasions the same man, working on the same machine, did the same job in 31 and 33 hours respectively at intervals of about two months. Similar figures will always be obtained by giving a man several jobs all alike to do, and noting the time of finishing each one. This emphasises the necessity of not interrupting a man when he has got a job on the machine. Many foremen will be continually making a man change the job on his machine before he has finished it. Where this is frequently found to be necessary it indicates bad management and bad organisation. It is especially common when the job requires two settings—for instance, in planing the two settings of a valve-chest cover. A foreman will perhaps think that he is causing no loss of time in telling the man to take the job off after the first setting is finished, and put some other one on. It does, however, cause a decided waste of time, and should therefore only be done when it cannot possibly be avoided. For the same reason it is in the highest degree inadvisable to break into a lot of machines that are being made, for the purpose of getting two or three

of them finished before the others. The actual cost of this manœuvre will always be very great comparatively.

Fitters.—Any hand fitting that has to be done to any part of a machine before it is ready for the erectors should be done to gauge, just as the ordinary machining is. The fitters are best divided into groups. For instance, in engine work, one lot of men will always finish off the connecting rods and the other details, or will get the various parts from the stores, and return them to the stores as finished connecting rods ready for the erectors; another gang will fit the cylinders, another the bed plates, and so on. By this arrangement every man gets accustomed to his own job, and becomes more skilful at it than he would be if he did a bit of everything. The fitting of any part should on no account be commenced till all the parts that the fitter requires are ready for him.

The foreman should keep lists of all the finished parts that are required to fit, say, a pair of cylinders, or any other part of the engine, and should so arrange matters that all these parts are ready for the cylinder men when they are ready for the job, all drilled, so that the men have nothing to do but go on with the job till it is ready for the erector. All intermediate marking off should be done by the marker-off, jigs or templates being used whenever possible.

It is more important with fitters than with any other class of workmen that they should always be kept amply supplied with definite work, because it is such an easy matter for them to be apparently working, and yet doing nothing. They have facilities for wasting time which no other workman has, and there are in consequence more wasted wages paid to fitters than to any other class of workmen, due to bad management.

The amount of time that can be wasted by a man in fiddling about with a pair of cylinders, for instance, when he has not got everything there ready for him, is simply inconceivable. He is, for instance, left to hunt up the covers himself from some remote planing machine or face lathe.

He is often set on with the job before the covers, &c., are finished, so that he has to hang about waiting for them. He then marks them off with a pair of compasses, carries them to the drilling machine, or waits till a labourer comes to do so; waits for them to be drilled, then lets them into their place, marks off the holes on the cylinder casting with a scriber, takes that to the drilling machine, waits till that gets drilled, then goes to find the studs, which have often to be specially made, and so on, *ad infinitum*. There is no possible excuse for all this delay, except that of incapable management.

In most small works not the least effort is made to arrange all these things beforehand, although they have to be done every time a cylinder is made. According to the system here advocated, everything is ready done before the fitter sees the cylinder. All the parts are in the stores ready for him—glands, covers, studs, spindles, lagging, screws, cocks, lubricators, and everything else, as soon as he is ready for them, and he need not wait a single minute in getting on with the job. The cylinders are drilled to a jig whose number is specified on the drawing, so are the covers, quite independently. The studs have been lying in a drawer in the stores for six weeks or more, with a paper slip, stating what they are for, and everything else in the same ready state. This is the kind of thing that makes the difference between dear and cheap work. When the fitters have all done their part of the work, but not before, the whole thing is given to the erectors to put together.

Erecting.—No erecting should be allowed to be done on a job until *every part* of the whole engine is ready. When this is the case the erector in charge should have practically nothing else to do until it is finished. To allow a man to have about 20 jobs on hand at once is simply to invite him to waste his time. This latter is the specific adopted by incompetent management in order to prevent a man temporarily running short of work, owing to proper arrangements not having been made to supply him with all he

wants for one job at a time. A good foreman knows what the erector will want before he starts work, and has it all ready for him. There is then some possibility of comparing the time occupied by various men in erecting a job, which there is not when he jumps about ten times a day from one job to another. This is at least as undesirable in the case of an erector as it is in the case of a machine-man.

5. The golden rule for getting through the business of an ordinary workshop is, "Get things done." It is not a very original rule, but it is a most important one in an engineer's shop. There are such a lot of little things that always want doing, that unless there is somebody with some energy in charge the place will gradually get hopelessly behind-hand. If there is anything to be decided, decide it at once, and get it out of the way. Better to decide wrongly occasionally than leave things hanging about until the whole place comes to a standstill for want of a few decisions. It is the things that do not matter two pins one way or the other that take such a lot of deciding. If a thing has to be ordered, now is the proper time to order it, by to-night's post; then it will certainly be there when wanted. If it is left till to-morrow, the chances are that it will be forgotten, and it will not be in the stores when the fitter asks for it. Order everything from outside that you can get as cheaply as by making it yourself. If you make such things yourself, you use up your own tools, and fill up your own shop, cause additional work to your own officials, and do not get any profit out of them at the finish. This is when you have got as much work of other kinds as you want. If you haven't, you must keep your establishment together the best way you can with what work you can get.

Grindstones.—A well-known engineer remarked once, "Show me the grindstone, and I will tell you the quality of work that is done in the shop." It is, in fact, extremely important to keep this tool in proper order. If this is not done, the men will keep their cutters at work long after they ought to be re-ground, with the result that the efficiency of

the machines is very much diminished. The author believes that it would be well worth the while of any firm, except a very small one, to keep a man for the special purpose of grinding tools, especially if he can be kept supplied with other work when he has no tools to grind. The best angle to which tools should be ground for various materials to produce the best results is well known, and tools should therefore always be ground to a properly made gauge. The grindstone in most works is in such a really shocking state—*i.e.*, it is so uneven—that the grinding of a tool is a very dangerous job, and is likely to nip off a pair of fingers at any minute. There is generally nobody told off whose special duty it is to turn up the grindstone. If this is done frequently, say every day or every other day, it is a very light job, and is done in a very short time. Some grindstone troughs are arranged for two grindstones with their working faces in contact with one another, and moving at slightly different velocities in the same direction at the point of contact, so as to slowly grind one another down. This is said to keep both stones in good condition. Unless some arrangement of this kind is made, somebody should in every case be appointed whose duty it is to turn up the grindstone at definitely stated intervals, and the foreman should see that this is always done. It is a horrible job to do, and a man will always shirk it when he can.

Tidiness in Shop.—It is also a very important thing to keep the shop clean and tidy. The shops where the best work is produced are almost invariably tidy shops. There are no heaps of greasy waste lying about, no mounds of rusty cuttings, no long-forgotten castings, and certainly no castings or forgings in process of manufacture. We have already said that odd castings, which are intended to be "brought in some day," should be put in the stores, numbered, and booked, so that they can be found at a moment's notice when they are wanted, and the drawing-office supplied with drawings of them all, so that they can work them into their designs, when possible. As a matter of fact, however, these

old things are very rarely made use of. It is far better to throw them on the scrap heap straight away, although in some cases it requires a good deal of courage to do it. The same argument will apply to them as to worn-out machine tools—*i.e.*, it costs as much to make them up into engines, and make special drawings and fittings for them, as it does to build a new engine, and although it seems like a piece of vandalism to throw a good cylinder, or a nearly-finished connecting rod, for instance, on the scrap heap, because it does not happen to be of the standard pattern, it is really the cheapest thing that can be done with it in the great majority of cases. If some drastic measures are not employed with such things, they will rapidly accumulate till they choke up everything. Similar considerations apply to odd patterns, which it is no earthly good to store. They only use up space, and are rarely used again. They are far better burnt or broken up, and crossed off the pattern books. This should be borne in mind when making patterns—that is, how long they are expected to last. If they are only for odd jobs, they ought to be knocked together anyhow, and then broken up after the casting has been made, for they will in all probability never be used again. To make a pattern with elaborate care, on the most approved principles, when there are only one or two castings required off it, with no prospect of any more, is a sheer waste of money. Indeed, patterns get so grossly and wilfully ill-used in the foundry (because the moulders think it is "good for trade" to do them as much damage as possible), and need such a lot of repairing, that it may well be questioned whether too much care is not usually devoted to building them—that is to say, whether it is not more economical to build a pattern that will be knocked to bits in a comparatively short time, and then make a new one all out.

The cost and trouble of keeping the shop clean and tidy are really exceedingly small, and quite insignificant compared to the immense advantage derived from so doing. An untidy shop tends to produce careless men and bad work. Although

each man should be expected to keep his machine decently clean, he should not be allowed to waste time on it. Of course, "cleaning the machine" is generally synonymous with doing nothing, or "waiting till the foreman finds a job," or something equally important. It is usual to allow half an hour on Saturday, before leaving-off time, for cleaning the machines. As it takes a man on the average about five minutes to clean his machine, this half-hour is largely wasted; a quarter of an hour is ample for this purpose.

Anti-rust Composition.—It is most important to cover all finished work with an anti-rust composition which will absolutely prevent rust. Ordinary oil is perfectly useless for this purpose. A great amount of time may be wasted in re-polishing bright work which has been allowed to rust, either during manufacture or by allowing the finished work to lie about in the shop. If the latter is allowed, the work stands a good chance of being ruined. The stores labourer is to be held absolutely responsible for keeping all bright work covered with anti-rust grease. Once a thing has been polished; it must be kept covered with grease till it is finished, even at the risk of dirtying people's clothes. Various kinds of hard varnish are often recommended for this purpose, but we have never seen one that was efficient. The varnish gets knocked off, and leaves the surface exposed to the rust. Rust will also form underneath the varnish, even though it be not knocked off. The alternative is some form of moderately stiff *non-acid* grease, of which the worst feature is that it wipes off on people's clothes, though it does not allow the surface to rust unless it has been very thoroughly wiped off. Some time ago the author made a considerable number of trials of various compositions by polishing a large number of pieces of steel, numbering them, and covering them with these compositions. They were then left in the open air for many months. Other trial specimens were placed under water, and the results noted. As a result, he found that specimens treated in this way which had been

covered with a composition of crude petroleum, prepared by the Ragosine Company, were kept absolutely free from any trace of rust. This composition will not allow rust to form, even in the dampest atmosphere, unless all the grease is very carefully wiped off. A mere accidental wipe does not seem to expose the surface. The composition is also cheap.

Lighting the Shop.—The shop should be as well lighted as it can possibly be, not only in the day time, but at night. To stint the light at night time is another of those colossal blunders which are daily perpetrated in the name of economy. This is a truth which will be brought out with the greatest clearness by the time-curve system. The time occupied in doing a job in the winter will be seen to be almost invariably greater than that required for the same job in the summer, and the chief reason is that the light is better in the summer than in the winter. This operates in many ways. Suppose a man is setting a large job in a planing machine after dark. Every time he shifts it he has to walk round the machine to fetch and adjust his candle or his gas flame, and every part of the work takes him much longer to do than if he has daylight. Again, if a planer finishes a job, say, at 7 a.m., on a winter's morning before it is light, and has another job lying by the side of his machine ready to be set, he will not attempt to set it before breakfast, because he knows it is done so much more easily by daylight. Instead, he will "clean his machine" (which, of course, means do nothing at all; it is astonishing how busy a man can be doing nothing) till breakfast time, after which he will set to work. The average result is that a job takes a man about 10 per cent longer to do in winter than it does in summer, owing to the difference in light. The result will be worse, and possibly much worse, if such light as is available is stinted. The practice of making the men use small burners in their gas jets is stupid in the extreme, because it diminishes the output far more than the value of the gas consumed. This, again, is due to lack of imagination on the part of the management, and lack of perception of relative

magnitudes. Only close and systematic observations such as those we have been recommending will prove the truth of such principles as these. An engineer's shop, more than any other kind of factory, needs floods of light. Arc lights, Wells lights, gas, and candles should all be used if necessary. The whole place should be ablaze with light, and the more efficient the lighting the more economically will the place be worked, because the cost of the lighting is insignificant compared with the tremendous waste of wages that will inevitably be produced by its absence. Any engineer can prove the truth of this maxim who cares to go to the trouble of making a few calculations and time observations. One often sees in shops where the lighting is excessively bad, men using gas without any burners in the brackets, because there are not any to be had in the stores. That is the kind of waste of gas that wants watching. Men will also leave their gases burning at full flare when they are not being used, and after they leave work at night. That wants stopping. Also the system of gas pipes is often in such a decrepit state that more gas leaks away than is used. That also wants stopping. If the gas meter is left on for 24 hours, and its reading noted before and after, the amount of this waste can be measured, and remedial measures, if necessary, applied. It is *waste* of gas, and not *use* of gas, which should be restricted. We have already referred to the necessity of warming the shop properly. The temperature maintained should be 50 deg. at least. The manager should make arrangements for having it recorded every day, so as to keep before his mind his duty in this respect.

On very cold days it may be necessary to provide buckets of fire, but they should not be necessary except during very severe weather, because they spoil the polished work, and produce an unhealthy heat. The men will not work properly unless the heating is properly attended to. A cold shop will also have a very prejudicial effect on their timekeeping.

Apprentices.—It will pay any firm to treat their apprentices well, and to devote some attention to training them. The

usual custom is to get an apprentice into the shops at a low wage, and set him to a screwing machine, or something else of equal calibre, and keep him there for several years, or as long as he will stop. The result is that he does not get any sort of a proper training. Not only is this unfair to the boys (who practically give their services in return for instruction), but it is very prejudicial to the interests of the firm. The idea with which apprentices are received should be to train the boys to fill useful positions in the service of the firm. An intelligent boy will well repay training, even though he leaves the firm's employ the moment he is "out of his time." During the last couple of years of his apprenticeship, if he has been properly trained (but not unless), he is practically as good as a man (and *may* be a good deal better than most), and as he works for one-third of the wages, or less, it is certainly worth going to the little trouble involved in training him. If he has not been properly taught, he will not be any use worth mentioning. When his time is up, there is a first-class trained man at the disposal of the firm, who is well acquainted with their practice, and whose abilities are known to the foreman, unless they drive him away to another shop, by refusing him fair wages on account of his youth.

Paying Wages.—There is often a good deal of dissatisfaction caused among men by being kept waiting for their wages on Saturday. It is one of those things which good management will not tolerate. The whole thing can be done in five or six minutes if arrangements are properly made. The cashier will usually know every man by sight in a small place, so that there is no need to make any special arrangements to prevent one man from getting someone else's money. In the case of an absent man asking another man to get his money for him, no money should be given to anybody but its rightful owner unless a *written* request is presented from the absentee. Any other arrangement renders the firm liable to be defrauded.

Testing and Experimenting.—There is no respect in which modern methods differ from old-fashioned ones more than in the adoption of the practice of practically testing every article manufactured by the firm, and the continual striving after improvement. Yet it must be remarked with regret that the great majority of firms in this country do little or nothing in this direction. Nothing can more surely indicate that a firm is—slowly, it may be, but none the less surely—on the down grade than that they are contented with things as they are, and are unwilling to change their methods or their practice to suit modern requirements. It is this self-satisfied conservative laziness that is doing more than everything else combined to drive away trade from the country. Foreign firms, often or usually of recent foundation, are slowly driving us from every market which was formerly exclusively ours, largely owing to the fact that we are contented with obsolete machine tools and machinery which has long been superseded, without making any effort either to cheapen design and manufacture, or to improve construction. The "fifty years" argument, to which we have frequently referred, is positively fatal to improvement and advance. It may be laid down as an axiom, that the fact that things have been done in a certain way for fifty years is usually the best indication that it is likely to be capable of alteration and improvement to suit modern ideas. No finality has been or is likely to be reached in engineering, and every manager should make it his chief object to keep his eyes open to improve or cheapen construction. All the best firms keep a special department and special staff solely for the purpose of testing and experimenting with finished plant and improvements. They are always willing to give a trial to what is likely to be a step in advance. These trials are conducted by careful and scientifically trained experimenters. The most that is attempted in an ordinary small works is to give the machine a rough sort of trial to see whether it will work at all (and even that is comparatively rare), and if so it is sent to the customer without more

ado, to take its chance. We do not wish to advocate the miscellaneous testing of every article made by the firm, still less the wasting of a single penny over scientific fads such as useless testing for its own sake, but simply to emphasise the fact that if a firm, without careful and accurate experimenting, sticks closely to one design, their experience of that class of machinery cannot be any greater, and will almost certainly be much less, than it was at the time of the last test made, and that the results of a carefully conducted test are of greater pecuniary value to a firm than the cost of making the test.

To take an instance, suppose a firm starts to make gas engines without making any experiment to ascertain the amount of gas consumed per B.H.P. per hour, corresponding to different designs. However many of such engines they make, they cannot be said to be increasing their experience of gas engines, nor improving their manufacture. In fact, they know no more about gas engines, but rather less, as time goes on. "Experience" is *not* gained by making the same thing for twenty years. A go-ahead firm will gain more experience in twelve months than a slow-going one will in twenty years. A similar remark may be made about that much abused expression, "practical man." A practical man is not one who has done the same thing for a long period, but one who has had experience in the real sense of that term. A man of *experience* is a man of *experiments*—*i.e.*, is one who has either made experiments himself, or (using that term in its broadest sense) who has got into his head the results of other people's experiments, knows what they mean, and has common sense enough to apply them.

A real practical man can often get more experience from reading a good book than another man can by twenty years' management of a shop. We do not hold a brief for the book-made engineer, who is perhaps more useless, if possible, than the ignorant, self-satisfied individual who is in the habit of miscalling himself a "practical man." A good technical book is simply a summary in a concise and

intelligible form of the experience of its writer. Another man may absorb that experience without going through the mill himself, just as a man may learn to make a good steam engine without starting with a tea kettle, after the manner of James Watt. It is imperative that one man's experience should start where his predecessor's left off. That experience will die and be lost if it is not committed to writing, and this record is what the self-styled "practical man," in his pitiable ignorance, calls "theory."

No firm, however, can get all their experience from books. They must know certainly and definitely what they can do themselves, and not what other people can do. That is to say, it is an absolute essential that every firm should experiment on their own account. Experimenting costs money, of course, and it costs trouble and thought, but it is unfortunately absolutely necessary, not only in order to advance but also to avoid falling back. It is becoming more and more unavoidable owing to the increasing practice of purchasing firms to insist on quantitative guarantees of efficiency. If a firm has never tested its own steam engines, it cannot possibly guarantee with safety, say, that one of them will work with 18 lb. of steam per indicated horse power per hour, however confident it may be about the perfection of the manufacture of the engine.

A firm who make milling machines or any other kind of machine, do not know so much about their own milling machines as an intelligent workman who has used one for a few years, unless they make careful quantitative tests of what their machines can do. It is no test to a high-pressure steam engine to run it for a few hours with wet low steam, to see if it will turn round. If it is designed for 180 lb. of steam, if it is tested at all, it must be tested with 180 lb. of steam while doing its proper amount of work. If a firm are to safely guarantee that one of their engines will work with, say, 18 lb. of steam per indicated horse power per hour, they must have tested a similar engine under similar conditions. It will not do to get the figures out of a book on

the steam engine. If this is relied on, the firm stand to lose as much over a single order from a determined customer as would pay for a year's experimenting. It is no economy to refuse to spend money on tests, any more than it is on tools.

In designing a series of tests, the firm must, of course, ask themselves, "What do we want our machines to be able to do?" and the next, "How are we going to test what they *will* do, and record the results of the tests in such a form that our designers can make use of them with the greatest certainty?" In cases where the article to be tested can be tried in the works itself, a special part of the shop should, when possible, be set apart for such tests to be made, and proper appliances procured, and they must be made under the conditions which will obtain in practice. A man must be employed in some capacity in the works who is properly trained to make the tests when necessary, and who has enough common sense to be accurate without calculating horse power to five places of decimals, and indulging in similar absurdities. In a small works a special man cannot always be afforded for this purpose. In this case an educated draughtsman must be told off for the purpose. It is quite a mistake to assume that any workman or foreman is capable of making such tests. A laboratory-educated man is an absolute *sine quâ non*.

Those who have had experience in engineering laboratories know that few people can even take a reading from a pressure gauge properly and accurately, unless he has had some training in taking and recording observations. A training is at least as necessary in taking and recording observations intelligibly and accurately as it is in doing a piece of skilled mechanic's work. There are hundreds of draughtsmen to be obtained who have had such a training, though a much smaller number who have the requisite common sense—that saving virtue of the engineer.

When the plant is a big one that cannot be tested in the works, arrangements should be made to test it *in situ*, and

provision should always be made in the estimate. Not only is this desirable in the interest of the manufacturing firm's experience, but it is also eminently desirable for their reputation. It gives the customer a good impression of the firm that he is not likely to lose if he sees them putting themselves to a great deal of trouble and expense to ensure the satisfactory working of the plant supplied. Such tests are often carried out under the supervision of the head draughtsman, who takes with him a staff of observers from the works or office. The tests when made are recorded or copied in the Tests Record Book, D IX.

In this book are kept records of all the tests made by the firm. In it are entered full particulars of every test made, with all the readings and all the results as calculated from the readings.

The head draughtsman makes all entries in this book himself, and checks all the calculations relating thereto. The test-book is ruled as shown on page 182.

All the observations should be plotted on curves when possible, on squared paper, and the curves pasted into the record test book, along with such things as indicator cards, and every piece of information connected with the test. The note-books (provided by the firm) in which the observations are recorded should be numbered and stored away. They should be strongly bound. When the observations are entered up by the head draughtsman into the book D IX, he should enter the test number in the note-books, so that the meaning of every test and the meaning of all figures should be perfectly clear when reference is made to the test in the future. The ideal to be aimed at in all such matters is that everything which has been done should be perfectly intelligible to a stranger who sees the books for the first time. There are, of course, some kinds of engineering produce which are incapable of a working test which can be recorded in this way. But tests should be made whenever possible, and the records of them kept in a special book. Some things, such as machine tools, can be tested for accuracy

and rapidity of work. In these cases accurate observations should be taken of the magnitude of the microscopic deviations from accuracy which are always found in even

TEST RECORD BOOK, D IX.

Test No.....
Order No.....
Working Nos.....
Note-books Nos.....
Test of.....
Test made by.....
At.....Date.....
Object and description of test made.....
Remarks.....
Observations.....

Results.....
Test made by (signed).....

the best made tools. One eminent firm of toolmakers known to the writer record these deviations as measured by specially made micrometers in the case of every machine they supply, so that if any question arises afterwards on

this subject, they are in a position to state definitely the condition of the machine when it was sent out. A special inspector is kept for this purpose, who has unqualified instructions to reject everything that does not come up to a strictly defined standard of accuracy.

CHAPTER VII.

COST-KEEPING.

Cost-keeping.—The object of cost-keeping is twofold. It is, firstly, to localise profits and losses, so that the firm may be able with certainty to tell, down to the smallest details, what part of their business is paying them and what part is not. Its object is, secondly, subsidiary to the making of estimates—that is, to give the management accurate and reliable experience of what has in the past been the cost of similar work to that of which it is desired to estimate the cost.

Estimate making, pure and simple, is quite distinct from the determining of the price to be quoted to a customer. When a manager has the estimate before him, the question that he has to ask himself is, What is the greatest price that, considering all the commercial circumstances, can be put on this estimate for profit, so as not only to secure the order, but not to choke off future orders? The maker of the estimate, on the other hand, asks himself what is the probable price for which this can be made in the works (taking into account all the expenses of the establishment of every kind), so as not to lose by executing the order. He has to consider circumstances connected with current prices of material, the present condition of the shop, &c.; whether the acceptance of the order will involve overtime; whether the order will involve the buying of special tools, and similar things. The process is largely one of a speculative character, and consists of guessing from more or less reliable data and

experience what the *actual* cost of the work will be. These data are collected and furnished by the costs office, whose function it is to provide accurate figures, which will not only gauge the accuracy of a previously made estimate, but also will furnish figures for the guidance of those who do the estimating in the future. It is in reality a perfectly straightforward job, and consists in intelligently following a system of recording all the sums spent in all the various ways in which money is spent in an engineer's shop, and in classifying them in such a way that all desired information can be most conveniently obtained.

In a small shop doing general work a very considerable amount of intelligence is necessary in carrying out the system, and it is much more difficult to do it in a small works than in a large one, because in the latter case a staff of officials can be told off to look exclusively after the keeping of costs, whereas in a small works not only does the work vary much more than in a large one, so that the methods cannot be so cut and dried, but it is not usually possible to have a special staff exclusively for this purpose, and the result is that, unless considerable care and intelligence are exercised, the costs that are kept will be in such a confused state that they are of little use to anybody, or they will be not infrequently extremely misleading, or kept in such little detail that their utility is greatly impaired.

The part of the cost-keeping that belongs to the shop and office respectively must be clearly defined. The division of the work is on the same principle as we have consistently advocated throughout, namely, that no book-keeping must be done in the shop that can possibly be done in the office. In cost-keeping the function of the shop officials is to furnish accurate detailed information to the office in an unclassified form. The wages are condensed from the time sheets into the time-sheet book, and subsequently posted from the time-sheet book into the costs book. The materials used in executing the order are posted into the costs book, partly from the invoices and partly from the outwards and other

stores books. The classification of the material thus provided is done in the office. The persons responsible for the accuracy of this information are, in regard to materials, the storekeepers. If the storekeeper is not reliable and intelligent, the costs cannot be accurate in regard to the materials used. In regard to wages, the same thing may be said of the foreman and the timekeeper, both of whom, but especially the former, are, and should be, held entirely responsible, under the system we are explaining, for the accuracy and intelligibility of the wages record. It is obvious that as all the information is, in the first place, derived from the time sheets, the first care of the manager must be that these are absolutely reliable, and not only so, but absolutely clear as to their meaning.

It is hopeless to attempt to get through the large amount of work that the costs office have to do, if they have to be coming into the shop every five minutes to see the foreman about the accuracy or meaning of the records from which they have derived all their information. It is for this reason that we insisted so strongly on the careful inspection of the time sheet by the foreman. If the timekeeper is sufficiently intelligent, he will be able to stop any unintelligible information before it gets as far as the costs office.

The actual cost of executing any order always consists of three distinct parts :—

1. The cost of the material of which it is made.
2. The cost of the workmanship, or the wages directly expended on it.
3. The cost of keeping up an establishment in which the work is done.

Now, the total amount of the first two can obviously be found to any desired degree of accuracy, after the work is finished, by keeping a record from the storekeeper's books and the timekeeper's books, as will be presently described, of all the items entered against that number. These are the obvious elements of the cost, and can be put down in the

costs books definitely and certainly, provided sufficient care is taken to ensure the accuracy of the books.

The other element of cost is by no means so obvious nor so easily determined. It is clear, however, that some allowance must be made for it, because, if the other two elements only were reckoned, it would be quite possible for a firm to sell their goods at apparently a big profit, and yet on the whole make a severe loss, owing to the cost of keeping up the establishment, paying interest on capital, paying rents and taxes, paying for gas and coal, paying managers' and clerks' salaries, paying for water and fuel for the engine, paying for the thousand and one items all of which are as necessary to the production of the article as the material and wages are, and without which it would not be possible to produce anything at all. Now, the general question of the amount which is to be charged for these items is no part of cost-keeping proper. It is a question for the estimator to consider. Cost-keeping is, however, directly concerned with recording the total amount spent in keeping up the establishment. This amount is ascertained only at the end of the year, by the same process as is used to ascertain the special cost of executing an order. But as it is impossible for the total cost of an article to be considered without taking account of them, we shall deal with them here as briefly as possible as elements in the cost of each article. If it were possible to locate these charges to the various orders, it might legitimately be held to come directly under cost-keeping proper, but as a matter of fact it is not, even approximately. For instance, it is not possible to even estimate how much gas is used by men working on any particular job which would not be used if this order had not been executed. Nor is it possible to say how much of the foreman's time is occupied in looking after men working on it. Even if it were, the foreman's wages would be running on if the order had not come, so that it is obviously impossible to charge any part of the foreman's wages direct to any particular order. In some cases, however, even this

might be possible, as when the whole of a shop is given up to executing a big order. But even then it might probably lead to endless complication if there were another shop close at hand belonging to the same firm, and having anything in common with the other one.

In a general case, however, the only possible way of determining the *actual* cost is to calculate, at the end of the year, say, what has been the total cost of keeping up the place, and divide this amount according to some arbitrary system among the various orders executed by the firm in that time. It is clear that this cannot be done until the end of the year, but as it is important that final costs should be got out within a very short time after the order is completed, the amount added in practice to the appropriated cost for establishment charges is only an estimate of what the actual establishment cost has been. Now, when this item has to be allowed for on an *estimate*, not a guess, there are obviously two things to be estimated, namely, what will have been the total cost at the end of the year, and secondly, what will have been the amount of work that has been turned out of the shop during the same period. After this the amount can be divided according to the system determined upon. So that the estimated establishment charge would be on this system an estimated fraction of an estimated amount, calculated on an estimated system. The object of the estimator is to so co-ordinate his system to the expected amount of work that will in all probability be turned out, that, at the year's end, the total amount that has been allowed for establishment charges, when added up, will more than cover the total actual cost.

Division of Establishment Charges.—The question then arises, What is the best system to adopt in dividing this total estimated cost between the various orders? It might be thought at first sight that the simplest and best way would be to divide it in the proportion of the rest of the cost, which latter can be more easily determined. According to

this method, the amount charged to cover the establishment expenses on any order would be

$$\frac{\text{appropriated total cost of order}}{\text{appropriated cost of all work done during year}} \times \text{total establishment costs during year};$$

or in other words, establishment charge = appropriated cost of order $\times \frac{\text{total establishment cost}}{\text{total appropriated cost}}$.

That is to say that a certain easily calculated percentage of the total cost actually booked to the order is added to cover the establishment charges. Further consideration, however, will show this to be wrong. Take an illustration. A firm might get an order for a large piece of machinery which consisted entirely, or almost entirely, of castings on which very little work had to be done, the execution of which —assuming for the moment that the patterns are already in existence—would consist merely in finding the pattern out of the pattern stores and sending it to the foundry ; obviously this could have been done without the keeping up of the whole establishment ; so that if its value is great, it ought not to have to bear a proportional amount of the whole establishment cost, since any number of similar orders could be executed without in the least increasing the total establishment expense. Suppose, on the other hand, a piece of work is ordered, the raw material of which costs very little in comparison to the work which has to be done on it. The men necessary to do the work would need a large amount of space, gas, supervision, bookkeeping, and so forth, and if this establishment charge were reckoned on the total value of the finished product, which might very well be relatively small, the amount actually charged might be much too small to cover the actual cost. On the other hand, the large castings might have to stay in the shop for a considerable time, and take up space which might be extremely useful to use for other purposes, so that it ought not in strict theory to be free from establishment charges altogether. But if one begins to calculate in this way what proportion ought to be

assigned to each order, one would have a pretty severe task, so that the plan almost invariably adopted is to reckon the establishment charges on the wages alone, and preferably to have a separate establishment charge rate for each department of the works. This is obviously nothing more than a convenient rough approximation, and cannot be taken to represent the actual establishment cost of any particular job. Two jobs might be exactly alike, and one of them be made by apprentices, when the wages bill might be very much diminished without diminishing the cost of keeping up the establishment, which the workers will need in order to produce the article itself, so that it is clear that even this method is not at all accurate in theory. However, this is the most convenient way of doing, and it is almost universal. The main thing to ensure is that the total amount charged for establishment cost in a year is greater than the actual cost. The establishment cost is, then, wages paid in executing the order $\times \frac{\text{total establishment cost in a year}}{\text{total wages paid in a year}}$, and it is the latter fraction that has to be determined. Again, it would be extremely inconvenient to have to estimate the amount of work which *will be* called on to share in the total establishment cost, so that the plan adopted in practice is to add a percentage to the estimated wages cost, which percentage is calculated from the experience of *previous* years, and it is only an estimate for the current year in a very rough sense.

Now, a considerable part of the establishment expenses arises from material which is used and dealt with solely in the shop, so that it is evident that any system of cost-keeping must include a method of keeping count of all the thousand and one items that are dealt with in the shop. As far as we shall be concerned with these items, we shall open accounts in the cost books for the various shops, and all materials will have to be charged to these accounts that cannot properly be charged to any other account corresponding to any particular order number. Similarly, there will sometimes be wages charged to "shop" which cannot be

put down to any order number. But this practice must be confined within the narrowest possible limits for obvious reasons. For instance, it would be a very easy thing for a foreman, who found that the cost of any particular order was becoming very high through some mistake or incompetent management of his own, to put down items on the men's time sheets to "shop," which ought to have been charged in the ordinary way to an order number. It will check this tendency to a large extent if the rule is made and adhered to that there is nothing to be done in the shop except under some definite order number. When anything wants doing in the shop, the foreman must not put it in hand till he has procured an order for the work from the office. For instance, suppose the foreman finds that a shaft wants to be repaired or a crane mended. He writes full particulars on a form, which he sends into the office. This is entered up in the main order book, and the office send back a formal numbered order for it, and the work is done under that order number in the ordinary way. This method has the additional advantage of enabling the manager to see what work is to be done in the shop itself, and to find a convenient opportunity to carry out any alteration that may be in contemplation when work falls slack. The ordinary process will then, of course, apply to obtaining any material for any alteration or repair that may be required in the shop. There will, of course, be trifling jobs to which it will be absurd to give a special order number. In these cases the foreman must take care—as always—that the job is fully described in the time sheets. When this is done the costs office will be able to do what is necessary in regard to the matter, as long as they have accurate information to work on.

Having thus taken a preliminary survey of what there is to do in the costs office, and the part played by the works departments, we shall proceed to consider the work of the costs office in detail. The work consists of posting to the account of each order number (1) the material used for it;

(2) the wages paid to men actually working on the job; (3) a certain previously determined percentage of the latter to cover establishment charges. It consists in analysing each account, as far as may be necessary, and in collecting the establishment charges of each department of the works into separate accounts for the current year.

The form in which the cost books are ruled will automatically analyse the material used for an order into its various parts. The only two classes of appropriated expenditure are those for material and wages, with which we shall deal in succession, and afterwards complete the consideration of establishment charges.

It is convenient to have the material and wages for one order number side by side. This is accomplished by devoting each left-hand page of the cost book to the materials, and the right-hand to wages, each being differently ruled, as will presently be seen.

CHAPTER VIII.

MATERIALS.

Materials.—At first sight it seems a very simple thing to enter in the cost book, from the stores outwards book, all the articles that have been given out for one particular number. It is not by any means so simple as it looks. The materials used in the execution of an order are of many different kinds.

Castings and Forgings.—In the case of a works having their own foundry, the material used is in the form of pig iron or scrap. Those having their own forge use material in the form of unworked iron or steel. Most small shops, however, procure their castings and the larger forgings from outside, ready made, and this is generally by far the cheapest thing to do.

The foundry is an entirely separate department, and when the firm work their own foundry, its accounts should

be kept entirely separate from those of the works proper, and castings should be delivered to the workshop just as if they had come from another firm. It cannot be denied that it is always a great convenience, and in some cases an absolute necessity, to make one's own castings, as all the delay that is usually caused by waiting for delivery from the foundry is thus avoided. Work can be pushed on in a way that is impossible when the convenience of other firms has to be consulted. But, in spite of this and other advantages, it appears to be the general experience that it is more economical for small firms to buy the castings and forgings ready made from firms who do nothing but make castings or forgings, as the case may be.

Patterns.—It also very often happens that firms can get patterns made outside more cheaply than they can be made at home; but unless the drawing-office is extremely reliable, and can practically produce drawings free from any kind of mistake, it is a very dangerous experiment to order the patterns from outside.

The pattern shop is the place where the mistakes (if any exist) are almost certain to come to light, and they are very often of such a kind as only those thoroughly familiar with the particular class of work can detect. In any case, when patterns are made outside they should always be brought to the shop to be measured over before being sent to the foundry. In this case the cost of the patterns comes under the head of materials.

Sundries.—Then there are the thousand and one sundries that are required for a job such as are handed over the stores counter. In addition to this there are articles which have been already made and finished in the works to a stock working number. It is in the latter class of materials that the greatest difficulty arises, and is the cause of more bungling than any other sort of materials. For instance, let us suppose that in the order we have been considering, for two 7 by 6 engines, there are already lying in the stores, entered up in the heavy stock book (S XII., page 76), four 7

by 6 connecting rods completely finished. It is decided to use two of these. When these are handed over the counter of the stores, what are the store-keeper and the cost-keeper to do? In many small works no definite accounts are opened in the books for these stock jobs. The result is that the cost-keeper cannot find out what is the cost of the connecting rod, and in consequence the whole cost of the engine, as ultimately arrived at, is incomplete, and a guess has to be made at the cost of the connecting rod. It may be generally stated that if any item of the work done in the shop is not completely costed up, errors of this kind are always liable to occur, and it should be made an absolutely invariable rule that the cost must be kept of every single order that is issued. As surely as a number is given to an order, so surely should the cost of executing that order be kept. There is no telling when it may be required, and it is almost certain to be required sometime. In the case of repairs executed about the shop when reliable establishment cost accounts are kept at all (which is by no means always the case), they are often bundled together in the cost books under "establishment charges' or something similar. In our opinion this is entirely wrong. If an order number has been procured for, say, repairing a crane, a separate account should be opened in the cost books for the job, just as if it had been an order from outside the works. The total cost of this work should be posted in the general account, with a reference to the detailed account.

In the case of the connecting rods above referred to, the store-keeper, in addition to making the outwards entry in the Heavy Stock Book, § XII., enters the giving out of the connecting rod in the Outwards Book, § X., in the manner given on page 194.

The working number to which the connecting rods were made was 5,250. This number is stamped on each rod. When the cost-keeper sees this entry in the outwards book, he looks up the cost of these four rods and divides it by two, and he thus finds the cost of two rods, which he enters to

order number 15,760. In the case of other heavy stock, such, for instance, as castings which have been rejected owing to some mistake, and which, since they cannot by any manipulation be charged to the foundry, it has been decided to keep in stock with a view of utilising them at some later date, when these are actually used (if, owing to some unusual good luck, this can ever be managed) there will always be sufficient references in the heavy stock book, such as date and drawing number, to show what the castings cost. This can then be entered to the account in the ordinary manner. It is clear that not all the materials which are used can be entered in the cost book from the outwards book. Castings, for instance, are in some cases not entered in the latter at all. In strict theory they ought to be, because when

Date.	Quantity.	Description.	To	Marks.	Size.	W.N.	Weight.	Remarks.
14 2/98	2	Finished connecting rods, 7 × 6.	Wright, No. 176.	5,270	7 × 6	15,760		

castings first arrive they are supposed to go into the stores and be entered in the inwards book as having come into the stores. When they are put in hand in the shop they are theoretically handed over from the stores to the order number, and therefore should, in strict theory, be entered in the outwards book. In practice, however, they are often taken direct into the shop, and unless the store-keeper enters them in the outwards book to the order number as soon as they arrive—which is superfluous, seeing that they are entered in the inwards book—they never touch the outwards book at all. Some of the larger firms keep what they call an

"unmanufactured stores," in which such things are put until they are wanted in the works. When this is done there is no difficulty about entering them in the outwards book to the various order numbers when given out. In a small works, however, there is not usually space for this, nor is there any real reason for it. The castings are at once taken into the works, and the store-keeper loses sight of them, so that separate provision must be made for such things to be entered in the cost book apart from the outwards book.

It often happens, however, that castings can be dealt with in exactly the same manner as other things, and it is indeed very desirable when it can be done. It depends largely on the situation and size of the stores. An excellent plan is to allow nothing to leave the stores or be taken into the works without a foreman's docket order on the store-keeper. This saves the storekeeper from the necessity of making the entry at the same time as he gives the article out, and ensures that everything used will get into the outwards book.

The stores entries are not so numerous in a small works that the cost-keeper cannot understand the various kinds of entry in the outwards book. It may be necessary for him to see the store-keeper occasionally, if there is anything he cannot understand, but this will be comparatively rare. He is not likely to confuse, for instance, an entry such as that given as a sample in the outwards book (S X., page 73) with some stores given out to a particular job, and, as we have said, it is extremely desirable to make his book-keeping as simple as it can possibly be, so that it is not desirable to multiply his books more than necessary. The only instructions he requires in the system that we are now explaining are—"Enter everything you get in the inwards book, and everything you give out or send away in the outwards book, and fill in every column that you can." Difficulties will occasionally arise in regard to such things as, say, lubricators that have been in the stores a long time. The cost-keeper

will perhaps be unable to discover the invoice for these goods immediately, but the heavy stock book or something else will usually give him the approximate date which will enable the invoice to be found. These cases will, however, be very rare, and to provide for them it would not be advisable to complicate the store-keeper's book-keeping. It might perhaps be arranged that the store-keeper on giving such things out should write in the "Marks" or "Remarks" column the date or some other reference which will enable the cost-keeper to locate the invoice. Stocks, however, are not usually so numerous or extensive in a small works that there is any serious difficulty of this kind.

The invoices are all compared with the inwards book in the office. It is not advisable for the store-keeper to be troubled with the invoice itself, for more than one reason. Firstly, because it is no part of his business; secondly, because he ought to furnish in the inwards book an independent account of what he receives. His account cannot be entirely independent if he is told what to expect by the invoice. If he receives the invoice before he gets the goods, he will often make his entry in the inwards book a fair copy of the invoice, and any errors of the latter will be reproduced in the inwards book. For instance, if a batch of castings arrive, which according to the invoice weigh 1 ton 5 cwt. 3 qrs., whereas their actual weight is 1 ton 3 cwt. 3 qrs., he will be very apt to reproduce the mistake if he has seen the invoice and is saddled with the duty of checking it. No observation of any kind can be independent if the observer knows what to expect. The checking of the invoice should consist in the comparison of the store-keeper's entries with those of the invoice, and in the checking over of the calculations. When this has been done, and any errors that may exist on one side or the other rectified, the cost-keeper may at once enter the castings or forgings under the order number in the cost book from the invoice, and tick them off in the inwards book and on the invoice to show that they are done with. All other items he enters from the outwards

books, and ticks each off as it is done with, making sure that it has not been entered before. Every entry in the outwards book must be entered to some account or other in the cost books, except such as refer to the sending away of articles out of the works. These are dealt with by the commercial department, with which we have nothing to do. It may be advisable for the store-keeper to enter these things in a separate book, but there does not seem to be any need for an additional book for this purpose, as the entries in it would be so few in number.

The Cost Book itself is a very large book, with very wide pages. At least one page is usually devoted to every contract or account of any considerable size. Perhaps the most convenient way of ruling it is to enter up the materials on the left-hand page and the wages on the right. At the head of the book is a full copy of the order, the working numbers and the order number, date of order, date when completed, &c. It is, in fact, an amplified copy of the information contained in order sheet A (page 42). The left-hand page is ruled as shown in the accompanying form (page 198).

The chief thing to ensure is that everything which is supplied for that order is entered into it, and hence the imperative necessity of passing everything that is used through the stores. If a thing has passed through the stores, there is no possibility of its being omitted in the cost books, because the moment the store-keeper deals with anything in any way he puts it down either in the inwards book or outwards book. It is not uncommon in some works, when something is urgently wanted for an order, for the foreman to send somebody to the cashier's office, over the head of the store-keeper, to get some money to send out for what is wanted. This is not often necessary except in very badly managed works, but when it is done it would probably be entered in the petty cash book, without finding its way into the costs book at all, whereas if it had been done in the ordinary way, through the store-keeper, it could not have missed the cost book.

Costs Book Materials. Page 552.

Order number, 7257. **Working numbers, 15760, 15761-2-3.** **Date, 29/viii./97.**

Full description of order.....

Drawing Nos., 14/72, 14/84 9/45 7/43 16/208 18/175. Gen. arr., 1/94.

Materials.

Date.	Quantity or number.	Description.	Reference. Invoice.	Reference. Stores.	Weight. Cwt.	Weight. qr.	Weight. lb.	Rate.	Castings, iron. £ s. d.	Castings, brass and G.M. £ s. d.	Forgings. £ s. d.	Iron and steel. £ s. d.	Fittings. £ s. d.	Sundries. £ s. d.	Remarks.
27/2/98	2	Castings:– Cylinders	S/12	I 121	3	1	7	12/–	1 19 9						
2/4/98	2	Special lubricators.	P 122	O 47				9 6					0 19 0		
27/4/98	1	Bar, 2½ in. round steel	L 78	S 28	1	2	4	18/–	1 1			1 7 8			
				Totals..											

Grand Total.....£ | | *Cost Summaries*, page.....

Order completed.....

References.....

The ruling of the cost book will almost explain itself, taken in conjunction with the illustrative entries that we have given. In cases where the castings cannot be entered in the outwards books the first entry of the castings would be made from the invoice, after this had been compared with the inwards book. Reference is made to the number of the invoice, showing where it can be found. Reference is also made to the entry in the stores book. I/121 refers to the stores inwards book, page 121. The cost of each item is entered under its appropriate head, so that they can be added up separately. The entry under "Iron and steel" is, of course, taken from the iron book, and S 28 gives the reference. Any ready-made part of the engine procured from outside is entered under "Fittings." Under "Sundries" are entered such things as oil, pipes, lagging, and anything else that cannot be classified under any of the other headings.

CHAPTER IX.

COSTS—WAGES.

Wages.—The total of the wages spent on any order is obtained in the same general manner as that already described in the case of the materials—*i.e.*, each separate amount is posted into the cost account from the time-sheet book.

The object of the time-sheet book may not be self-evident in cost-keeping. At first sight it might appear that the simpler and more accurate way of posting up the wages account would be to take the entries direct from the time sheets, thus dispensing with the time-sheet book altogether as far as cost-keeping is concerned, and also apparently avoiding the labour of keeping this book. It will be remembered (see pages 90 to 103) that the object of the time-sheet book, on the system that we are describing, is two-fold. It is firstly used to collect the time spent each

day by each man on each separate job, so that the total time occupied in doing any particular job can be added up and posted into the time-work book. It is also used with the same object, in order that a certain sum of money, spent as wages on the same job, may be posted into the cost book. The author, at one time, endeavoured to save the labour necessary to keep this time-sheet book by posting in each case direct from the time sheets both into the time-work book and into the cost book. The experiment was very far from being a success, for the following reasons:

A batch of time sheets are, of course, delivered to the time house every evening, relating to the work of that day. After being checked over by the time-keeper, they were first used by the man who was making up the piece book (page 93). The inconvenience of having to make up the times in this book from daily batches of papers will be easily understood by considering a sample case. The time occupied in turning and finishing a certain cylinder cover for a 24 in. cylinder was 32 hours, of which 2 hours were spent on the first day, $9\frac{1}{2}$ on the three succeeding days, and $1\frac{1}{2}$ hours on the fifth day. The time sheets were dealt with every day by the man in charge of the piece book, T III. (page 93), who had, therefore, to keep a running account of each of the jobs going on in the shop in order to arrive finally at a correct total when the sheet showed that the job was finished. This account was exceedingly inconvenient to keep in the piece book. In practice, it was kept by putting the totals up to date in pencil, rubbing the mark out each day when a further time had to be added, and putting the total in ink when the job was finished. The keeping of the time-sheet book would be amply justified to save this intolerable nuisance alone. The case is still worse when the cost books are considered. The sheets were sent up to the costs office each day after the time-work book had been made up, and there were, therefore, no less than five entries to be made in the cost book for turning the cylinder cover before the job was done. The number of entries, therefore, in the cost book was, on this

system, enormous. It will be easily seen how the keeping of the time-sheet book, in reality, far from adding to the labour of time and cost-keeping, enormously diminished it. The time-work book has no running accounts, and one totalised entry in the cost book suffices to finish off every separate part of the work. For each job there is one, and only one, entry. Apart, however, from this consideration, the time-sheet book is, of course, almost an essential when chalked boards are given to the men to write up their time on, for it is obvious that the cost book will be very rapidly reduced to an appalling state of filth if the man who makes the entries in it has to be fingering dirty chalked boards at the same time. The writer, however, knows one firm where this horrible state of things prevails.

We have already stated that the left-hand page of the cost book is devoted to materials, and the right-hand page to wages. This method is fairly general. The chief difference between the method of cost keeping that we advocate, and that generally adopted, is that the account is here kept in more detail. It must be remembered that the object of keeping the cost book as far as the works are concerned as distinct from the commercial department is twofold, which we may describe as the synthetical and the analytical respectively. The primary, and perhaps the more important of these objects, is that under all circumstances whatever method is adopted, or whatever labour is involved, the final result—which is the finished product of the costs department—*i.e.*, the total cost is the exact sum which the article in question has cost to make. Now, if this were the sole object, it might be secured at the expense of a very little labour, viz., by merely calculating and entering up under one heading all the unclassified amounts under that number from the stores books, the time books, and the invoices. This process would give accurately the bare sum of money, but, of course, nothing else. But even at that it would be infinitely superior to the chaotic scrawls which many firms dignify by the title of cost accounts.

The next step towards perfection would consist of keeping the accounts for materials and wages separate still in an unclassified state, the castings, forgings, and fittings, &c., being all mixed up together on the one hand, and the wages for turning, pattern-making, fitting, &c., being also mixed up together on the other.

A still further stage would be attained by the use of suitable ruling in the cost book, such as that shown in the last article, which automatically analyses the various amounts under their respective headings. This principle of ruling is also adopted in the case of wages, of which a sample page is shown herewith.

Now, on the wages side, we advocate doing what is the universal custom to do on the materials side, namely, to enter the particulars up in such detail that every item of wages can be exactly accounted for. This is not usually done, on the score of trouble and expense, and also because it is not possible with the crude systems of time boards usually adopted. If the shop does not furnish particulars to the costs office, it is obviously impossible for the latter to classify them. That it materially increases the labour of cost keeping cannot be denied. It is to be feared that many engineers will condemn it on that ground. We contend that it is at least as important in the case of wages—and in our opinion much more so—than it is in the case of materials, because without it there is absolutely no check on the sums that may be wasted as wages, whereas there are dozens of checks on the costs of materials, invoices, quotations, and price lists, and so forth.

As we have already said several times, there is a decided tendency for engineers to be too material in their views. Materials are visible ; time spent in working is not. But it is expensive for all that. Few people, nowadays, would call money spent in maintaining a perfect system of commercial book-keeping as wasted, and a precisely similar argument would apply to maintaining a perfect system of workshop book-keeping—for that is what cost-keeping really amounts

to. There are few firms who would consider the following to be an adequate entry on the materials side of the cost books—"Castings, £5 7s. 3d."; yet the same firm would be quite content with the entry—"Turning, £1 5s. 6d."

The great advantage secured by this detail may not be apparent at first sight, but anyone who has tried to investigate the cause of an abnormally high cost will be able to appreciate the lesson to be derived from the following illustration taken from actual practice:

A set of machinery had been ordered from a firm of engineers. The price quoted had been £35. Previous sets of precisely similar machinery had been made, of which the total cost had been about £26. When the job had been proceeded with, a further order was received from the same firm, which consisted of an alteration to certain parts of an existing machine and fitting it to the new machine with which it was destined to work. No price had been quoted for the latter order, which was to be done on day-work. It had been originally intended that the second order should be executed at the customer's own works, but it was subsequently decided that some parts of the old machine should be sent to the engineer's works, in order that the new machine might be made, as far as possible, to suit the old one. This was done. When the cost of the new machine was made up, it was found to be slightly over £36. The costs were entered up without the details being specified in the wages page. The abnormally high cost was, therefore, unexplained, it being attributed to the influence of a strike which had occurred about that time. The foreman could offer no explanation, but made a casual remark to the effect that he had had to plane one of the brackets twice, in order to carry out an idea of the customer. Then the explanation began to dawn. It appeared, on further questions being asked, that several finished parts of the new machine had had to be altered in order that it might fit the old one, and that, further, several parts of the old machine had had work done on them, and that this work had been

put down to the order number of the new machine. Now, if this fact had not been accidentally discovered, owing to a purely casual remark of the foreman, the customer would have had his alterations effected for considerably less than they had cost. Even as it was there was no chance of making up a correct account owing to the incomplete character of the entries. Now, if a proper system of recording the wages spent had been used, the mistake could not have been made, and, if it had been, would have been immediately and certainly detected by a comparison of the new records with the old ones. If the cost had been actually higher, the cause of it could have been immediately detected by the same means.

The cost of any particular work will vary, not only in different localities, but also as between different shops in the same locality, and even also in the same shop from time to time according to the efficiency of the workmen and of the management. If the cost of a standard pattern of machine be found to be increasing instead of slowly diminishing, as it ought to do, without any visible cause, such as rise in materials or in the rate of wages, it is obvious that either the machinery, or the workmen, or the foreman, or management is not so good as it used to be, and a careful inquiry ought to be made into the cause. Now if there are no accurate and detailed costs to go on, it may well be altogether impossible to locate the trouble. The management may elect to sack the foreman when he is quite blameless in the matter. In fact, it may be altogether impossible to say what is the cause. When, however, each item is specified in detail, there will generally be little difficulty in finding it. There is another advantage, which in many cases is extremely important, and that is the ability to analyse the costs into the various parts which may be required. There are a great many cases where this analysis is impossible. In a machine in which there is a great deal of fitting of one part to suit another, it is obviously impossible to say which of those two parts has cost the money. When

all work can be done to gauge, on the other hand, this difficulty disappears. As we have said, gauges and similar things can only be profitably used when a large number of exactly the same kind of articles have to be made. Where only one article of a sort is made an elaborate set of gauges and templates would clearly be a mere waste of money, so that firms who do this class of business are handicapped when it comes to cost keeping. But, even in that case, firms are constantly having to quote for parts of their own machines, which may have worn out, and it becomes in the highest degree desirable to be able to pick out of a previous cost account the item which will have to be repeated in order to supply the required part. Of course, when it is desired to introduce piecework rates, this method is positively invaluable; a piece price can be certainly quoted for any part of a machine of which accounts kept on this principle are in existence. These considerations would seem to indicate that in most classes of work a cost account which does not furnish complete details is deprived of very much of its usefulness. The ruling of the wages side of the cost book (page 206) will be found perhaps as convenient as it can be made. Sample entries are given, which will show the *rationale* of the system. In regard to the columns giving machine rates, the next chapters will explain the method advocated.

We have already said that nothing should be allowed to be charged to "shop" without its being exactly defined. Of course, this remark only applies to the skilled labour. It is a great mistake to attempt to charge labourers' time, and cranemen's time, and similar things, to the individual order numbers. It is quite impossible for men employed on such miscellaneous jobs as these men are, to give any account of the way in which their time is occupied. If it is attempted, the time-sheet keeping simply develops into a time-wasting farce.

Overtime Rates.—It is a question to what extent the extra rates paid for overtime should be charged to the jobs on which the men are actually working during the time

Date.	Part.	Job.	Name.	No.	Time occupied.	Rate.	Establishment and machine. Rate.	Establishment and machine. Cost.	Drawing.	Pattern-making.	Turning.	Planing.	Slotting and shaping.	Milling.	Drilling.	Other machines.	Fitting and marking.	Grand total.
									£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
7. 11. 97.	2	Connecting Rods.	Turning and fitting	Evans.	126	38½d.	11d.	2 15 0			2 5 0							
8. 11. 97.	2	Cylinders...	Milling valve faces and steam chest flanges	Silcock	29	30½	32½d.	1 4 2						0 18 5				
9. 11. 97.	2	Cylinders...	Fitting	Broad...	53	29	32½	5d.	0 12 1								1 1 6	
							Totals..											

after ordinary hours. Of course, there may be cases where the extra amount paid in wages can fairly be charged to the order numbers, but in a general way it is certainly more logical to charge all extra money paid in overtime to establishment charges. By "extra money" we mean, of course, wages paid over and above the ordinary rate for the time actually worked. For instance, two hours overtime are paid for as two and a half hours. The extra half hour's wages is what we have called extra money.

There are several reasons for this. Firstly, we have already pointed out that the more work that is done in any year, the less is the amount of establishment expense per pound's worth of goods manufactured. If the extra money paid in wages is charged to the establishment account, the result will be a tendency to equalise this ratio.

Now, as a matter of fact, what is the reason that extra wages have to be paid above normal rates for work done in overtime? Clearly, the reason is that the shop is so full of orders that they cannot be got out in normal hours of work. In general it is not due simply to the order which is being worked on that extra rates have to be paid, but to the fact that the shop is very full of work. It is therefore clear that in justice to all jobs in the shop, the extra rates ought to be spread over all the jobs to which the pressure of work is due, and not to the one which may accidently happen to be worked on during the overtime. If the other jobs had not been in the shop, this order would have been executed during the normal hours, and therefore it is very unfair to saddle it with the extra rates which have been rendered necessary by the existence of other orders. Again, by charging the overtime rates to the job worked on, the whole object and aim of cost keeping is stultified. That object is to gauge the efficiency of the works. If costs are liable to large fluctuations independently of the efficiency of the works, it is perfectly clear that they no longer act as a check on that efficiency. During a very good year the cost of every individual article may go up considerably, due

simply to the extra rates paid for overtime, even although the actual efficiency of the works management may be much greater than it has ever been before. At the same time the establishment cost per pound of wages paid may drop considerably, due to the increased output, although there may be some great loss going on, and which may be undetected because the establishment cost is low. It will be thus seen that from every point of view it is unadvisable to charge the extra rates due to overtime to the job actually worked on. By charging them to establishment it is possible to compare always the actual cost of two similar jobs under similar conditions, whereas, under the other system, no cost account is of any real value for purposes of comparison when overtime is being worked in the shop. It also tends to keep the establishment rate uniform, and also distributes the increased cost in the most equitable way.

Lumping of Wages.—There will often be cases where the wages of two or more men may be lumped together. Thus two riveters and a holder-up may often be classed together. Similarly with a smith, a striker, and a hammer boy. The smith never works without the striker, so that they are both reckoned together, and labour is thereby saved.

CHAPTER X.

Costs—Establishment Costs.

Establishment Cost Accounts.—The primary object of keeping establishment costs is, as has been said, to ascertain the sum which is required to keep the shop going per pound of wages paid. We have already shown that this is the most satisfactory way of reckoning establishment costs, but it is not entirely satisfactory, because, although the total establishment cost does vary *with*, it does not vary *as*, the total amount of wages paid. The establishment rate is, in fact,

some inverse function of the total turnover; that is to say, efficiency of management being constant, the greater the total amount of wages paid in a year, the greater will be the *total* establishment cost, but the less will be the establishment cost *per pound of wages*. The latter is, to some extent, a criterion of excellence of management, but by no means altogether. For instance, it might well, and usually does, happen that a judicious increase in the total management cost would be attended by a greater decrease in the shop expense. Now, it is obvious that the main object to be striven after is, not to keep the establishment cost down on the one hand, nor, on the other, to keep the shop expense down, but to so arrange matters that the sum of the two is a minimum. That is the best management which effects this end for a given turnover, irrespective of the absolute magnitude of the one component or the other.

Establishment cost accounts are generally kept in a very slipshod way, and are regarded by many cost clerks as a convenient dumping ground for items that would cause a certain amount of trouble to enter in their proper place.

We have already referred to the tendency to charge against "shop" on the shop time sheets far more time than there is any justification for. This tendency must be rigidly held in check both in the office and the shop. It is not the function of the workman nor the foreman to decide to what account in the cost books any particular amount is to be charged. This is the underlying principle of the system of time sheets which we have explained fully in previous articles. As far as cost-keeping is concerned, the only duty of the workman and the foreman is to furnish to the costs office exact accounts of what has been done in the shop, so that the costs office will be in a position to charge to the proper account. The tendency to charge to "shop," in order to save the trouble of entering an item to the proper account, is, however, by no means confined to the works. Many cost-keepers themselves are flagrantly careless in this respect.

The subject of establishment cost accounts naturally divides itself into two parts: (1) The reckoning up and classifying of the amount *actually* spent in keeping up the establishment during each year; (2) the division of this total amount among the various orders executed in the shop.

If it were possible to wait till the end of the year before making this division, the problem would be very much simplified; for by that time not only would the total amount spent in keeping up the establishment be accurately known, but the total amount of work done and wages paid could also be found, and there would be no difficulty in devising some equitable way of dividing the total expense among the orders. In practice, however, as has been already pointed out, the final cost of an article has to be got out within a very short time of the completion of the order, and the amount charged to cover establishment cost is, at best, only a rough estimate of the actual cost.

To keep the establishment account correctly is a highly complex piece of book-keeping. On the one side of the account are the actual expenses incurred in the current year in addition to the stocks carried over to next year; and on the other are the various amounts charged against the different order numbers (the latter being regarded as each paying a certain share of the general establishment cost), and the stocks as carried over from last year. The latter are of an exceedingly complex kind, and there is no wonder that perfect, or even moderately good, systems of cost-keeping are so very rare. A cost-keeper, to be really efficient, must be not only a trained engineer, but must have a very thorough knowledge of book-keeping, and these two qualifications are very rarely combined. It is obviously impossible in a few articles to deal exhaustively with this extensive subject. Our object is only to discuss the general principles which should govern the costing system in a small works, without touching on purely commercial matters more than can be avoided. As

stated above, we shall divide the subject into two parts, the first dealing with the calculation of the total expense actually incurred by the various departments (this corresponds to one side of the cost account); and secondly, the way in which this total expense is borne by the various order numbers (corresponding to the other side of the account).

The Ascertaining of Total Establishment Cost.—Although on the surface this would seem simple enough, it is, in fact, a most difficult thing to carry out satisfactorily. It can be done, however, after a fashion with as much ease as the other parts of the work previously described, viz., by lumping in one account everything that is spent that cannot be charged under any particular order number, and adding up at the end of the year.

As will presently be shown, this rough-and-ready method is far from being satisfactory. For instance, it does not admit of any satisfactory comparison being drawn between different years, since any year's account may include large items which, though they are actually spent in the current year, ought properly to be distributed over a number of years, and which are so large as to completely mask ordinary differences between one year and another. Thus, a crane may break down, and may cost £100 in repairs. These repairs, though made and paid for in the year under consideration, have been gradually rendered necessary during a number of years, and the beneficial effect of the repairs will be felt over a number of years to come. It is therefore obvious that items of such magnitude ought not to be charged to one year's account. A few such items in a single year's account will obviously swell the total to relatively enormous dimensions, so that any little saving effected in such things as gas, oil, or files would be altogether lost sight of. Nor does this rough-and-ready method distinguish between the various shops or departments, so that a most extravagant *régime* might be in vogue in one department, the waste due to which, being but a small fraction of the total establishment cost, might remain undetected for years.

Special Department Cost Account.—The first point that we shall make is that each department of the works must have its establishment cost account kept separately.

Many engineers dispute the necessity or desirability of this, and are content to lump them all together in the way we have described above. The argument with which they are content is, that so long as their customers on the whole pay for the total upkeep of the establishment, it does not matter to them which of them does it. If they charge in every case, say, 75 per cent of the wages cost to cover establishment charges, and it is found that at the end of the year the total amount so charged adds up to a greater amount than the sum of all the items included in the establishment account, they are satisfied. In our opinion, this is a most vicious principle to work on. This, again, arises from want of clear perception of the reality of establishment cost. It would be quite as reasonable to argue that as long as the shop pays a profit, it does not matter that there is a loss on some jobs and a double profit on others. It might, and almost certainly will, result in many cases in so inflating the apparent prime cost of that part of the trade which is most profitable as to kill it altogether, while in others the firm may be unconsciously selling their goods at so low a rate as not to pay them. There is, of course, some force in the contention that in many classes of business prices are adjusted not so much by prime costs as by the prices charged by other competitors, and that unprofitable orders have to be taken in order to secure the profitable ones, so that very fine observations of costs are out of place, since they have so little to do with adjustment of prices. This does not touch our contention that an employer ought to know with great exactness what each article of his manufacture costs him, so as not only to show him clearly whether costs are increasing or the reverse, but also to put him in the position of being able to encourage and develop that part of his trade which is the most profitable to him, and to abandon the rest without misgivings. If the principle that we are arguing

against is correct, it ought to hold good under a wide range of circumstances. Now, it will be found that the establishment expenses in the machine shop are invariably much greater than in, say, the fitting shop. If, then, the 75 per cent mentioned above as an average all round is charged in all cases, then all the work done in the machine shop is undercharged in respect of establishment charges, while that done in the fitting shop partly pays the establishment cost of the machine shop. If for any reason one of the departments were shut down, the rate of establishment charges would, *ipso facto*, become entirely wrong, and at the end of the year it might well happen that there would exist a large deficit in the sums charged for establishment cost.

Again, in the case of a firm adopting this principle, in quoting a price for a piece of work consisting largely of fitting, it would be quite possible—and there can be no doubt that it is a thing that very often occurs—to lose an order owing to the excessive amount estimated for establishment expenses, which would, in fact, never be incurred in executing the order, or, on the other hand, to get an order at an unprofitable price owing to sufficient not having been allowed for to cover the establishment cost which would actually be incurred in, say, the machine shop. The objection of many firms to analysing their accounts in this way is the more surprising, because it can be done with no extra trouble. It is simply a question of the page or column on which certain items are entered. It seems obvious that it is impossible to check the extravagance of any particular department unless the accounts of that particular department are kept separate from those of other departments. If, for instance, the cost of coal in any particular year is abnormally high, it will be obviously impossible to do more than make a guess at the reason if all coal bought is lumped into one account. The chances of detection are certainly much increased if the waste of coal can be traced to its proper department. Similarly with

gas and other similar things. A separate gas meter should invariably be supplied to every shop where this is possible.

It will be obvious that there will be a large number of amounts which cannot be entered against any particular department of the works. Such items as managers' salaries, rates and taxes, and so forth, often cannot be charged against any one department, but must be common to all. The establishment cost accounts are, in fact, to be treated as though orders, such as the following, had been received from customers—"to maintain and provide for the working of one machine shop (for instance), and supply all necessary material and labour for that purpose."

Classification of Establishment Cost Accounts.—The various departments in the name of which accounts will have to be opened in the costs books will be, for instance, as follows: Commercial office, drawing office, stores, pattern shop, machine shop, foundry, fitting shop, smithy, &c. These are the special department accounts. In addition there will be accounts for expenditure which is common to all the departments, such as power, general management (including salaries of general managers). Further, there may be accounts which are merely the details of other accounts, such as stationery, wood for patterns, &c. All amounts, when possible, should be charged to the special department which incurs the expense, but in a great many cases there will be amounts which cannot be charged to any special department, and which will, therefore, have to be charged to the general account. But the practice of "charging to shop"—*i.e.*, to the general account—will have to be held in check as far as possible, just as in the case of the works. Very often it will happen that two or more departments will have to have some items in common, but which are so far special to the departments concerned that they cannot justly be charged to the general account. The drawing office will have many things in common with the general office, such as stationery, duplicating apparatus, and other things, and the cost-keeper will often have to com-

promise between them in order to avoid unduly increasing the number of cost accounts. Of course, it would be possible, by a huge multiplication of accounts, to avoid this altogether by opening special accounts for such things as "stationery," and so forth, and the cost-keeper will have to decide how far this is justified by the special circumstances. It is generally as undesirable to needlessly multiply the accounts as it is to needlessly lump them all together. A judicious compromise between too many and too few is here, as everywhere, desirable. The accounts should be just so many as to make it fairly obvious to which of them each amount is to be charged, while avoiding, as far as possible, the necessity of charging a great number of items against general expenses. At any rate, however many accounts are opened, every item of expenditure, of whatsoever kind, must be entered up to one or other account in the cost books. The sum of all the cost accounts ought to be the exact total sum spent by the firm in the year under discussion. It is desirable to have a special book, specially ruled, for the establishment costs. This may be ruled, if desired, on the same principle as those already explained in the case of the materials and wages. A specimen ruling is appended. This is perhaps as convenient as any, and avoids, to a very large extent, the multiplication of separate and distinct pages for the various accounts.

Of course, it is just as important to economise the cost-keeper's and the clerks' time as it is the workmen's. Clerks' time costs money just as workmen's time does, and labour-saving appliances—such as phonographs, speaking tubes, and typewriters—in the office are just as desirable as other labour-saving appliances are in the shop. It appears to be overlooked by many engineers that if a clerk is paid one shilling an hour, every five minutes of his time that is saved is a clear gain to his employers of one penny; such a thing as a typewriter often saves its cost in six months.

Productive and Unproductive Departments.—Now, it is fairly obvious that all these accounts to which we have

referred do not bear the same relation to one another and to the general accounts of the establishment. Some are subsidiary to all the others, and some are merely the detail of other special accounts. It is obvious, for instance, that when all the sums that have been entered up to the machine shop account are added together, the sum so

ESTABLISHME

Date.	Quantity.	Description.	Rate.	References.	General office.		Stores.		D. O.	
					Materials.	Wages.	Materials.	Wages.	Materials.	Wages.
					£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s.
	20 lb.	Glue	3d.	I $\frac{30}{39}$						
	10 barrows	Horse dung	1s. 6d.	S $\frac{7}{42}$						
	50 ft.	Deals for shelves 222—227.....	9d.	I $\frac{30}{121}$			0 5 6			
	14	Hours work on ditto (Martin 202).....	36s.					0 9 6		
	14	Hours, boy	12s.						0 3 2	
	10 gals.	Creosote for lighting.....	3d.	I $\frac{30}{35}$						
	1 week	General labouring	23s.							

obtained will of necessity be smaller than the total sum required to keep the machine shop running. For before the machine shop can be kept running, it is necessary that the office work should also be kept running, that the managers' salaries should be paid, &c., &c. Certain of these accounts, again, are what we may call secondary accounts, and are neither more nor less than the detail of some other account or accounts. They are kept perhaps simply as a check on

extravagance, and their total amounts are added to the primary account from time to time.

Now, the object of the existence of the works is to produce work. In order to do this the shop and the plant are erected. The shop and the plant, however, cannot be kept going without the assistance of the office. The latter may

COSTS.

Pattern shop.		Smithy.		Foundry.		Machine shop.		Fitting shop.		Boiler shop.		Power.	
Materials.	Wages.	Materials.	Wages.	Materials.	Wages.	Materials.	Wages.	Materials.	Wages.	Materials.	Wages.	Materials.	Wages.
£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
0 5 0													
				0 15 0									
						0 2 6							
									1 3 0				

therefore be regarded as, in a sense, a subsidiary department—*i.e.*, a department which does not exist for its own sake, but for the sake of the shop.

The departments must, in fact, be divided into what may be called productive and unproductive departments—that is to say, departments in which articles are actually made for sale, and departments which are subsidiary to these. Among the former are, of course, all the works departments

proper—although it is open to question to what extent the pattern shop and drawing office are productive departments in the same sense as the other departments are.

The higher the state of organisation of the establishment, the less will these two departments be what we have termed productive. In the great majority of cases these two departments occupy a position intermediate between the productive and the unproductive. Of course, if a shop were solely engaged in the execution of isolated miscellaneous orders, the two departments would be productive departments in exactly the same sense as the other departments are, inasmuch as all the work they would be called on to do would be just as essential to the execution of any particular order as the turning and fitting are.

But suppose, on the other hand, that all the orders received by the firm were for standard patterns of articles of which the firm make a specialty, none of which differed in any respect from orders which had been received before; then the two departments would be as entirely unproductive as the general office, in the sense that none of their work could reasonably be charged against any particular order. In the latter case the only use of the drawing office would be to make such small alterations in existing designs from time to time as experience might dictate, and to send out administrative orders, such as the order sheets, &c., to the foremen. The use of the pattern shop would be to keep in repair and to renew when necessary the patterns used in the execution of these standard orders. The fact that these standard patterns happened to need repair or renewal at the time when a certain order was being executed would no more justify the expense of that renewal being charged to that order number than would the fact that a large lathe needed repair at the same time justify the cost of that repair being charged to that number. Far from being any advantage to charge such amounts in this way, it is positively misleading, as it tends to put the management under the false impression that certain orders have been expen-

sively executed, when, in fact, they have not, and thus stultifies the whole object of cost-keeping.

In spite, however, of these considerations, it is a very common practice to charge repairs of patterns to the order which is being executed at the time, instead of to the establishment account; the result is that, as these events happen at odd times and irregularly, a great many firms cannot tell to 50 per cent what the execution of any order is going to cost, the reason, of course, being that their cost system is so badly designed as to be practically useless for its proper function—*i.e.*, as an *exact* indicator.

As we have said, patterns are often largely ruined by inadequate arrangements being made for storing them, and, if poetic justice could be done, their repair ought to be charged to a cost account headed "incompetent management." In some works the drawback to opening an account under this heading would be the difficulty of finding storage room for the cost-books. It is in practice a matter for the judgment of the cost-keeper to determine whether a charge of this character should be entered to the special order or to upkeep of patterns.

Now, the cost of such items as may be justly charged to general expenses are to be treated in exactly the same way as the expense of the upkeep of the unproductive departments—that is to say, they will have an influence on the establishment rate of future years, but they are dead as regards the orders executed in the current year. If a pattern is altered to suit the whim of a customer, or if a drawing is altered or a special design made for the same purpose, these charges ought, of course, to go to the special account, but general repairs and upkeep of patterns, or even the manufacture of special patterns which are destined to become standard patterns, should be charged to some account which may or may not be one specially opened for the purpose, which is treated in the same way as the account for new plant.

It is, then, obvious that as it is the productive depart-

ments which earn the profits, it is they which must pay for the upkeep of the unproductive ones, so that in addition to the charges which can be entered up to the productive departments direct, there will be further charges to be added at the end of the year, calculated on some more or less arbitrary system in such a way that their sum for all the productive departments will together make up the cost of keeping up the unproductive ones. The unproductive departments accounts are therefore subsidiary to the productive in just the same sense as the establishment costs of every kind are subsidiary to the order number accounts and as the secondary accounts are to the primary.

Somewhat similar methods will apply to dividing the cost of the power used in the works. It will be easy to make a fairly accurate estimate of the power used by the various machines. The total amount of the power account can be divided, as will be presently explained, in proportion to the amounts of power used in each case, and the sums so calculated added to their respective accounts at the end of the year. Every unproductive account is, in fact, a charge on the productive accounts, and each is divided between them in varying equitable proportions.

Depreciation and Repairs.—This is one of the most difficult items to deal with satisfactorily in cost accounts. It may not be evident at first sight that depreciation in the value of machinery should be taken count of in the cost books as distinct from the commercial books. In does, in fact, however, form a very important and difficult item of establishment cost. This will be understood by considering that the object of establishment cost accounts is to ascertain the cost of *maintaining* the establishment, and not allowing it to fall to ruin.

There is nothing theoretical or imaginary about this charge. One pound so entered is spent just as really as if the firm were to pay it away in wages. But it is, of course, spent in *kind*, and not in *money*. The reality of the charge will be clearly seen by considering the following case.

Suppose that a man starts business with a shop full of new machinery, keeping cost accounts very carefully, but not considering depreciation as an item of those cost accounts, although allowing for repairs. By the time he has been working for, say, twenty years (during which time we will suppose he has uniformly made a profit on each order according to the showing of his cost books), all his machinery is worn out, and instead of a shop full of new machinery, he has a shop full of scrap iron. In order to put the shop into its original condition it will be necessary to pay away a good part of the whole profit which his cost books may have shown him to make during the last twenty years,

It is thus clear that the profit his cost books showed was illusory, and was not his real profit. In order, then, to accurately estimate the real as distinct from the apparent

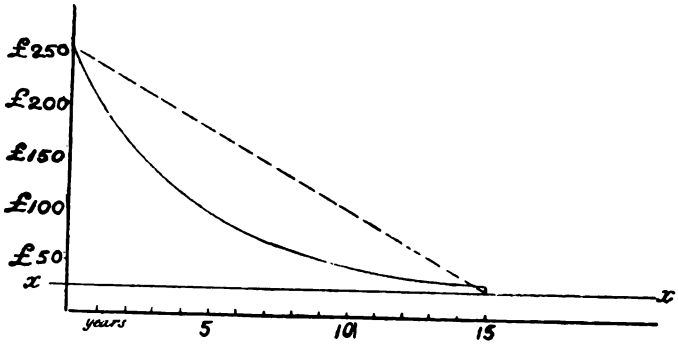


FIG. 4.

profit, a broad general view must be taken of the value of each machine from the time it is bought to the time it is thrown on the scrap heap.

When a machine is bought new, suppose its cost is £250. Now, the actual market value of that machine, after being used even with the greatest care, drops very rapidly in the

process of conversion from a new machine into what is, in spite of its being "as good as new," a second-hand machine. Its value to the firm may not and does not drop in the same way, but the price at which it could be sold does drop. Let us suppose that the price at which it could be sold varies as shown in the curve given in fig. 4. The minimum which it will always be worth is the price of the weight of scrap iron. This will, of course, fluctuate to some extent with the market, but it will be sufficient for our purpose if we assume that the price of the metal when sold as scrap is represented by a horizontal line $x\,x$, which is an asymptote to the curve of value.

Now, for practical purposes the value to the firm ceases when the machine has been in regular work for, let us say, fifteen years—that is to say, the firm would at the end of that time decide that it was not economical to keep the tool at work any longer, but would replace it by a new one. Now, the tool has obviously depreciated in value to the firm from £250 when it was bought to its value as scrap, less the labour of taking it up and putting a new one in its place, assuming this subtracted from the value of the old machine rather than added to the value of the new tool. This depreciation has taken place in direct consequence of the firm having done certain work with it for the benefit of customers.

As we have said, cost is not only money paid away, but also *money's worth* paid away; and on this definition part of the cost of doing the work for the customers, in whatever shop it is, has been that a certain part of the value of the machine has been paid away or lost. Thus it is clear that in order to find the actual establishment cost something must be put down every year in some account subsidiary to the machine shop account, in order to represent the depreciation in value of this particular machine. We shall presently discuss the question as to what account this should be.

Not only does a machine depreciate in market value, but

it needs from time to time money being spent on it in repairs. We have already pointed out that if sums spent for repairs are put down to the current year's expenses, the firm does not know how it stands, and it is impossible to tell how much real profit or loss has been made during any particular year, nor how much has been spent in establishment costs. The repairs, though paid for in and charged to the account of one particular year, earn their profit in other years—both the years during which the repair was being rendered necessary and those in which its beneficial effect is being felt.

The problem before us is, therefore, how much to charge to the cost account in order to represent the amount paid in kind—*i.e.*, the amount of the value of the machine—by keeping it running. It is clear that this amount cannot be calculated exactly until the machine is finally put on the scrap heap, just as in the case of the cost of an order, the amount spent in establishment expenses cannot be calculated until the end of the year, but an estimate has to be made of it from the experience of previous years. This experience is, as it were, crystallised in the previous year's cost accounts. Just as an establishment cost account is necessary, in order that a firm may have reliable data on which to base their estimate in general matters, so, if they are to have reliable data on which to base their estimate in the case of depreciation and repairs of a machine, they must open a separate cost account for each machine. This is very rarely done in practice; at the same time no cost scheme can be perfect unless it is done.

On one side of these accounts ought to be the original price of the machine and everything that is spent on it of a permanent character, such as permanent repairs or new attachments, and on the other an entry is made once a year of the amount which the machine has earned during the year, and which is put down in the general account for depreciation. There is very little trouble in keeping these accounts, and they form a most valuable record of the history of the machine, as well as facilitating stocktaking.

When the machine is finally scrapped, the total account can be balanced, and it will then be seen whether the machine has been a profitable investment or not—*i.e.*, whether it has earned as much as it has cost. It may be mentioned that in a future section we shall show how these expenses are distributed among the various orders on which the machine has been engaged, so that the customers on whose account the machine has been used in reality pay for the machine and its upkeep.

Now, we have pointed out that it is not possible to ascertain definitely how much ought to have been written off every year for depreciation and repairs of the machine until the individual account of the machine has been closed—*i.e.*, until the machine has been scrapped. It is, however, necessary to make an estimate for working purposes. This is done as follows: The price of the machine is known; the length of time that it will be kept at work is estimated, as is also the sum of money that will have been spent in repairs at the time that it is scrapped. This latter sum is added to the original cost of the machine, and the total is divided by the estimated number of years that the machine will be kept at work. This is the sum that will be put down every year for depreciation at first. As time passes on this sum may be increased or decreased, as may be found advisable. If it appears that the repairs to the machine are going to be less, or the machine is going to last longer, than was at first thought, it may be decreased, and in the other event, or if the machine seems likely to be superseded, it may be increased, if it can be consistently, and if not—that is, if the machine has to be thrown out before it has paid for itself—it will have to be written down an unprofitable investment. This is the price that the management will have to pay for their experience with that class of machine.

Without such accounts as this they cannot be said to have any reliable experience of them. They may take a captious liking for the machine, or an equally unreasonable dislike,

but it is impossible that their opinions on the subject can be reliable unless both the performance of the machine and its commercial history are definitely recorded in some such way as we have been recommending in this chapter and under time-keeping.

It will be seen that in writing off so much every year for depreciation alone, apart from repairs, if the amount so written off is constant, it is assumed that the value of the machine to the firm does not vary in the way shown by the curve in fig. 4, but as shown by the dotted straight line given in that figure. It would, however, be quite easy to determine the amount, so that the curve represented the assumed value of the machine at all stages of its history. In this case the amount written off during the early life of the machine would be greater than that allowed for at a later stage. This is, in fact, perhaps the best thing to do, viz., to assume a curve, and fix the depreciation by measuring the difference between the ordinates at the successive years' ends.

The only available alternative to this method consists of "re-valuing" the machine every year at the time of stock-taking. This is a most unsatisfactory process; firstly, because no two valuers will assign the same value to any machine. A personal element enters into the question, which at once vitiates the whole result. In addition, a critical examination of the process of valuation, as ordinarily carried out in practice, shows that it is in no sense an actual estimate of the value of the machine as it stands, but merely a rough calculation of a certain fraction of the value written down for it at the time of the last stock-taking. The valuer considers only one single year in the machine's history, whereas, when the process is effected by the curve method, not only is it done much more rapidly and certainly, but also the whole of the previous valuations are taken into account, and a definite scheme of valuation is fixed on which is entirely self-consistent and absolutely independent of the individual or valuer.

The curve of value of the machine plus repairs will be as shown in fig. 5. After every considerable repair the value of the machine may well be supposed to suddenly jump up by the value of the repairs effected, and to gradually sink nearer to the original curve.

Now, the special machine account acts as a sort of reservoir. The original price of the machine represents an amount of water put into this reservoir, and every repair effected is an additional amount. These amounts are all collected and

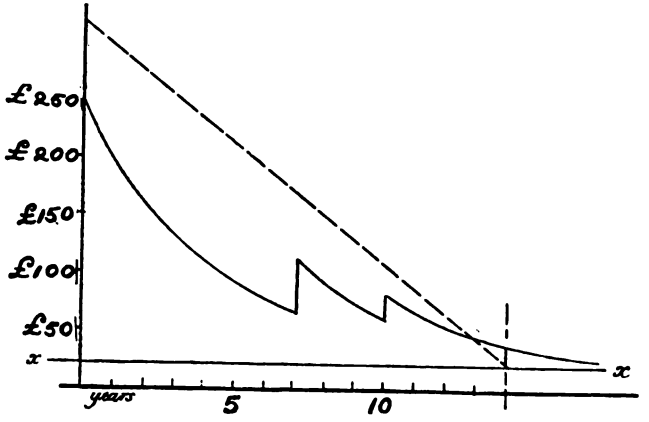


FIG. 5.

stored in the account, and so much is allowed to run out every year, so as to avoid unduly burdening any one particular year with the cost of a repair that does not properly belong to it.

The final curve from which the amounts for depreciation and repairs are taken is drawn through a point on the vertical axis, which is higher than that representing the price of the machine by an amount equivalent to the total of all the sums spent on the machine in repairs, &c.

The Division of Establishment Costs.—We shall now discuss a method whereby the many items of establishment cost

may be equitably divided between the order numbers. It is obvious that the price charged to the customer for the execution of any order over and above the actual cost of the materials and the wages paid, must not only provide for the establishment cost, but also for profit. We have already discussed the difference between what we have called the productive and the unproductive departments, or, what comes to the same thing, cost accounts.

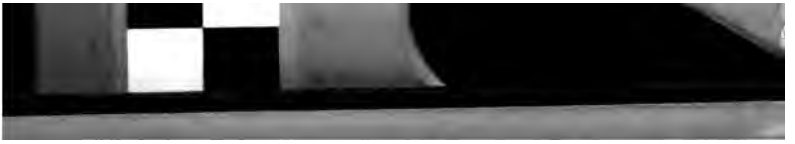
Now, broadly speaking, our method is as follows: The productive department accounts are considered to be the main establishment cost accounts. The unproductive ones are considered as subsidiary to the productive. Each unproductive account is added up at the end of the year, or half-year, as the case may be, and the total sum is divided in any equitable way among the productive accounts. There will be a different method of division of each account when necessary. Each secondary account is, in fact, considered on its merits, and divided up among the other accounts in the way that can be most equitably devised for that particular account. Thus, the account for power, in so far as it cannot be estimated in detail, as will be presently explained, will be divided among the departments in proportion to the power used in each. This can be done with some approach to accuracy. The gas account (if there are not separate meters for each department) will be divided in proportion to the number of gas jets in regular use. The interest on capital will be divided in proportion to the capital laid down in each department. Some of the accounts, for which no more equitable method can be devised, will have to be divided in proportion to the number of men employed in the different departments.

When any account is made up at the end of the year, the method of division—*i.e.*, the amount contributed to balance the unproductive account by each productive department—will, of course, be shown on the credit side of the account, and the amounts so shown will be transferred to the main accounts, and thenceforward treated in bulk as part of those

accounts. By this means the whole of the establishment cost is divided among about half a dozen accounts, representing the main productive departments of the works.

It must not be overlooked that there may not only be primary accounts (such as, say, the fitting-shop establishment account), and secondary accounts such as the power account or gas account, &c., but also there may be tertiary accounts—*i.e.*, accounts which are subsidiary to the secondary, such as the stationery account or the coal account, and even accounts of lower orders still—*i.e.*, accounts which are subsidiary to the tertiary accounts. All these accounts are to be carefully kept in their proper places at the final stock-taking.

Each account of whatever order is complete in itself. On the one side is the detail of the account, and on the other side are the sums that have been transferred to the accounts next higher in the scale, which latter are regarded as each paying a certain share of the former. Thus, take the stationery account. The total of this account might be divided between the drawing-office account and the general office. Suppose £30 of it is charged to the drawing office, and £63 to the general office. Those sums then become items in those respective accounts, and the stationery account for the year is closed, the drawing office being regarded as having paid £30 and the general office £63 to the account to balance it. Then suppose that the unproductive part of the drawing-office account, including the £30 just mentioned, amounts to, say, £543. This amount is in the same way regarded as being paid by the productive departments in any proportion that is deemed fair, and the amounts so paid are written off in the drawing-office account and transferred to the various primary accounts. By this means we get a number of total sums representing the cost of keeping up the various productive departments of the works, the sum of which sums is the total amount spent in keeping up the whole establishment, everything included. These totals are balanced in the primary establishment



accounts by charging each order number with a certain sum for every hour that is worked on it. Thus, if a man works, say, 7 hours in bedding down a shaft for W.N. 15627, and supposing his wages are 9d. per hour, a sum of 5s. 3d. is, of course, entered to 15637, and in addition, a sum of 5d. per hour (suppose) to cover establishment costs. The establishment is regarded as having earned this sum, which is entered up to it when the cost account is made up. The same principle is thereby carried out in balancing the primary establishment account by making each order number account bear a certain proportion of the expense. The order number accounts are balanced by the payment by the customer of the contract price of the job.

Little or no difference is made between the sum charged for apprentices in respect of establishment charges and that charged for journeymen. That is to say, the sum is charged per man per hour employed, and not per 1s. of wages paid. The reason for this is as follows: It is well known that when an article is made largely by apprentices, the cost of it appears to come out much less than is the case when full man's wages have to be paid. As no record is generally kept of the proportion of apprentice labour employed, it will be seen that the "cost" as generally accepted is only in a very loose sense any criterion of efficiency of management, as the cost is liable to immense fluctuations, independently of efficiency of management, the fluctuations being merely due to the amount of apprentice labour that has accidentally been expended on it. It is easy for any foreman to make any cost large or small at his pleasure by merely putting boys on the work instead of men. If the establishment costs are reckoned per 1s. of wages paid, this discrepancy is exaggerated, whereas, if it is reckoned per man employed per hour, it is toned down.

Here it may not be out of place to point out the absurdity of the practice which is so common of endeavouring to keep down the "cost" of low-priced jobs by giving all the work connected with them to apprentices. Of course, the actual

cost of such jobs is not thereby reduced by the fraction of a farthing. The actual English of this ridiculous proceeding is that other jobs from which the apprentices are withdrawn are saddled with a part of the cost of the "cheap" job. It is simply a process of cooking the cost accounts on the part of the management, with the object of deceiving themselves and shutting their eyes to facts which would become painfully obvious but for this ostrich-like manœuvre.

But apart from considerations of this kind, it is nothing more than bare justice that the charges for an apprentice should be about the same as for a man. A boy needs quite as much as a man of gas, supervision, and all the items that make up the establishment cost, and, this being so, there is no reason why an arbitrary and wholly conventional discrepancy of wages should make the customer pay less for the upkeep of the establishment in which he works than he does in the case of a man. Now, the sum of all these amounts so charged for any department ought to be at least equal to, and to exceed as little as possible, the sum total of the establishment cost of the department concerned. Cost keeping is mainly concerned with the determination of the above-mentioned rates. They are entered to the establishment account of the department concerned all at once, when the order number account is made up. For instance, suppose a man, number 157, whose establishment rate has been on the average 7½d. per hour, has worked during the year a total of 2,542 hours. The establishment is credited in various smaller sums with £79 9s. on that account, which represents the total of all the sums charged against various working numbers during the whole time. It can thus be easily seen at the end of the year whether the rates have on the whole been too high or too low, and alterations can be made in future years. Although a profit on the account is better than a loss, it is, nevertheless, not advisable to make a profit on these accounts. If this is done, what has been actually profit at the end of the year will not have been recognised as profit till that time, which is a disadvantage.

As has been already said, the desideratum is to make the two sides of the account exactly balance. This can be done very closely by an experienced man, especially when he can slightly alter the rate from time to time, according as he sees which way the account is running. Many circumstances may have an influence on the adjustment of the rate. For instance, if a shop is put on overtime, this should be the signal for the establishment rate to rise a point to pay for it. The amount of rise should be the result of careful calculation, so as to cover extra expenses only. It is the function of the commercial department accounts to show a profit, and the works departments account to show no loss, and as ittle profit as may be.

We shall now discuss the various departments in detail, and briefly consider the peculiarities of each.

Drawing Office.—We have already briefly discussed the question as to what extent this is a productive department in the sense in which we have used the expression. In so far as the drawing-office time can be put down to order numbers, so far is it a productive department, and is therefore a primary account. In so far as it cannot, it is a secondary account, which has to be divided among the primary. This secondary account is different from the corresponding accounts, which are primary accounts, of the other works departments, inasmuch as the work is really done for the whole shop, and not for any particular department of it. Thus, if the drawing office makes a new drawing of a standard engine, the work is really done for the whole shop, and cannot be either charged to any special department or to any order number ; whereas, when the turning shop makes a new countershaft, suppose, it is done for some special department, and not for the shop as a whole. There is in many cases, however, little to be gained by treating it differently from the other accounts, especially in a small works doing general engineering, and it may often therefore be treated as a primary establishment account. Of course, however, if a great part of the drawing-office work were

uncharged work, it would be completely wrong to do so, as it would altogether overload those accounts which required any special drawing-office work, with the result that the establishment rate for the drawing office will be very high, if the account is to be balanced.

The other items are not very considerable, and consist of drawing materials and stationery and the wages of the head draughtsman and general assistants. A large part of the time of these latter, and also of the draughtsmen's time, may generally be put down to special order numbers, except when the drawings, &c., have been allowed to get into a very bad state, either through original tracings being sent into the shop to work from, in which case renewal involves making a fresh tracing, or through the drawings being improperly or inefficiently indexed. For instance, when an order is received for a standard pattern, the getting out of the lists and the collection of the working drawings may very fairly be charged to the order number. Sometimes part of the head draughtsman's time may be put down to special order numbers, although this is not usually done, because, in addition to spending time on the particular job he has in hand, he has to exercise a considerable amount of time, thought, and attention in overlooking the other operations, so that the whole time during which he has been engaged on his own work cannot be fairly put down to the order number. The approximate amount of establishment expenses on an ordinary drawing office will be about 30 per cent or 40 per cent of the wages.

In our opinion it is quite a mistake to regard the work done in the drawing office as essentially unproductive. One often notices an assumption on the part of managers that the drawing office and the pattern shop are "unproductive" departments under all circumstances, because the things that are made in these departments are not actually to pass into the customer's hands. In our view this is entirely wrong. In general, it is an absolute necessity to make a pattern and a drawing before a casting or anything else can

be produced. This being so, the pattern maker and the draughtsman are as much producers as the moulder, and should be so regarded. It would be just as reasonable to regard the smith as a producer and the turner or fitter as a non-producer. All are alike necessary, and no absolute distinction of this character can be drawn between them. We have called the departments "producing" and "non-producing" only in the sense that the work of the one can be charged direct to the order number, whereas the other cannot always be so charged. In so far as they can be so charged they are regarded as producing departments. Two accounts are therefore to be opened for the drawing office; the one has to bear its share of the unproductive accounts, just as the other productive departments do, though, of course, in a different proportion. Thus, no part of the power would be charged to the drawing office, although a relatively large proportion of the general management cost would fall on the productive account, on account of the large amount of the managing officials' time which is spent in directing and instructing and supervising the drawing office.

Pattern Shop.—There appears to be much diversity of opinion as to whether the wood used for the patterns for a particular order number ought to be charged to that order number, or whether wood generally should be treated as a general expense of the department. There is no doubt that the former would be the correct method if it could be correctly done. The only difficulty is that without a special stores for the purpose it is almost impossible to do it accurately, and the cost of a special stores is greater than the results to be obtained would warrant. It may be attempted through the foreman, unless he has too much to do otherwise. If the returns have to be left to the men, it is sometimes thought better not to attempt anything of the sort, because it is certain that no accurate results can be obtained. If it is not done, the neglect is obviously equivalent to the assumption that the wood used by a man is in all cases proportional to the time he works. As this is very far from being true, it is

in our opinion better to reckon the wood to the order, even though it can only be done imperfectly. This involves the opening of an account for wood in the cost books, so that the wood bought may be checked against the wood entered up to the orders. The balance is to be charged to the general pattern-shop account. The ratio of establishment cost to wage in the pattern shop will be found to be usually somewhere about 60 or 70 per cent. Among the general expenses of the pattern shop are a share of the cost of power, if, as usual, there are any power-driven tools in the shop. Depreciation of the machines must be allowed for on the principle explained below.

Machine Shop.—As far as establishment costs are concerned, this is the most important account of all, partly because the actual cost of maintenance is enormously greater than any of the others, but also because much of the cost of it can generally, by careful observation, be allotted with some certainty to the individual order numbers. Great care is necessary in doing this, because there is a great danger of charging many amounts twice over—*i.e.*, both to the order number and to the establishment account. The principle which we advocate is as follows: We have shown how the depreciation of each individual machine can be estimated on a rational basis, and we have briefly shown that this depreciation is directly due to the fact that work has been done with the machine for the benefit of customers. We shall now show how much of the expense of running the machine shop may be charged to those customers for whose benefit this work is done.

The cost of running each machine consists of several distinct parts, and the amount of a great many of them can be estimated with some approach to accuracy. Thus the power required to run the machine may be closely estimated. An account should be drawn up in the drawing office showing the estimated expenditure of power in the whole works. The engines jointly indicate, say, 40 horse power. This corresponds to one side of the account. Some of the

big athes will require, say, 2 horse power each; a big planing machine, say 4½ horse power, and so on. It may, perhaps, be possible to estimate the horse power *at the engine* for each machine—*i.e.*, the actual horse power divided by efficiency of transmission. The latter function will, of course, be enormously higher in the case of electrical transmission than with shafting. The average efficiency for the whole shop may easily be roughly arrived at by indicating the engine at full load and also indicating it when the shafting alone is running. The difference between these powers, divided by the total horse power, will fairly accurately represent the efficiency of transmission, although it is not absolutely accurate, because the power required to drive the shafting when the load is on will be greater than that required to drive it when the load is not on. That is to say, the total power when the load is on will be greater than the sum of the powers required to drive the shafting light, plus the sum of all the powers required to drive each machine separately if all were driven by separate electro-motors. It is, perhaps, therefore best to divide the actual power required by each machine (which may be determined, if desired, by special experiment) by the aggregate efficiency mentioned above, and adjust the items in proportion, so that the sum of all the powers equals the total indicated power of the engines.

Now, the machines in a shop are of two classes, viz., those that work directly on the order numbers, such as lathes and planing machines, drills, &c. (or perhaps it would be more accurate to say those for which it is possible to calculate with some approach to accuracy by the ordinary processes of timekeeping such as have been already explained, the amount of time spent on each order number), and those machines on which it is not practicable to do this, such, for instance, as grinding machines, cranes, circular and band saws, and wood-planing machines, and so forth. Now, the cost of these latter falls on the establishment account of the shop concerned, those of the former on the particular order number on which they are working.

The amount of these charges can be determined as follows. The items of the cost of running the machine are as follow: (1) Power, which we have just shown how to estimate, which is reckoned on the same principle as machine depreciation and depreciation of engine, &c. (2) Depreciation of machine tools, which we have already dealt with: the amount of this item per hour is, of course, determined by dividing the total cost of the machine by the estimated hours that it will have worked when it is done with. (3) Interest on capital. (4) Rent, &c., labourers' wages, foreman's time, craneman's time, and use of crane, oil, gas, &c., &c. All the latter are to be lumped in one amount, as any further subdivision would be rather difficult and perhaps superfluous. The net result will be that there will be an establishment charge of so much per hour for each machine which covers the establishment cost for that particular machine, and as the machine-man never works without the machine, this may be put down, as already indicated in the cost book ruling, at the same time as the men's wages are put down. It is to be carefully observed that these amounts are not all put down in the general establishment account of the shop concerned, because, if they were, they would be charged twice over.

The amounts so charged are most easily dealt with as follows. The amounts charged to the order numbers for depreciation are added up for each machine at the end of the year, and are credited to the machine. The amounts allowed for the first three will be posted at the year end to the credit side of the special account concerned, and the last will go in a lump to the credit side of the general account. The machine is regarded as having earned amounts (2) and (3), which, therefore, help to pay for the machine, while the power installation has earned the amount charged to the order number for power. They are, in fact, part of the value of the machines, which has been paid away for the benefit of the customer, and they are, therefore, included in the machine account and also in the depreciation, being

automatically registered as depreciation by getting into the machine account from which the amounts for depreciation are calculated.

Care must be taken to avoid entering the depreciation part of the machines' earnings to establishment account. They are, of course, ultimately entered to capital account, since a depreciation of the machine means that part of the capital originally put into the building has been paid away on behalf of the customer, and the depreciation earnings will be required in future years to make good this loss. In a similar way the amount charged to the customer for power is credited to the power account, so that the power account is balanced. Of course, the cost of the power that is consumed by the general shop machines is also entered into the power account, and is posted from there into the general establishment account of the shops concerned, and is entered in the power account as having been transferred to the establishment account, which latter pays the unappropriated share of the power account. When a machine-man has to mend his belt or do some similar thing, this ought to be charged to the establishment, as it would be obviously unfair to charge it to the job on which he was working.

Fitting Shop.—The establishment costs of this part of the works are comparatively light. They consist chiefly of files, oil, supervision, waste, gas, fitters' tools, and so forth. These cannot, of course, be estimated in the same way as we have already explained in connection with the machine shop. The amounts charged for establishment rates may be calculated by dividing the whole amount of the establishment account of previous years by the total number of man-hours worked in that department during that year, increased or decreased as judgment may direct. In a great many works a crude attempt is made to charge files to the order number on which the man is working when the file is given out. We have no hesitation in characterising this as perfectly ridiculous. In practice a man usually requires a new file because he has to attack a bit of brass for a short time, and

his iron files will not touch it. To make this an excuse for charging the file to the job is about as pronounced a piece of convenient absurdity as could be found among the multitudes of bungles which most costing systems contain. The proprietors of these systems seem to think the firm is being robbed in some mysterious way if a file is entered to "shop," while at the same time they will pass without remark any meaningless or nonsensical scrawl which is put down in a hurry by a man who has been surprised by the unexpected arrival of the hour of departure. Fourpence or fivepence per hour is the usual amount to be charged per man in the fitting shop. Of course, there may be exceptional cases when files may reasonably be charged to the order number, such as, for instance, where a man is engaged for several weeks on a job, necessitating great use of files, and where it is reasonably certain that the file will be "jiggered" before the job is done. In this case regard must be had to the ordinary method of charging files. If they are bought by the hundredweight, and charged to the shop as soon as they come in, they cannot be subsequently charged to individual order numbers, as otherwise they would be charged twice.

Smith's Shop.—Few difficulties will arise in regard to the establishment cost accounts in this department of the works. The chief one is, perhaps, that of estimating how much steam is used by the hammers. These, as is well known, are extremely extravagant in steam, but the amount used is very difficult to ascertain because of the irregularity with which they are used. It is, of course, very rarely that a special boiler is used to supply steam to the hammers.

There are different ways of dealing with the iron used in the shop, and a correct treatment of this is difficult. The difficulty consists in the impossibility of getting a satisfactory way of treating the iron that is returned to the stores after a forging has been made. A smith may take a bar for a particular purpose, say, to make a shaft 7 ft. long, for which he is given a bar 8 ft. long, of which he returns 1 ft. to the stores. The question then arises whether the order

number is to be charged with the 8 ft. length or the 7 ft. length. In other words, is the 1 ft. to be entered in the iron book as scrap or as bar? Of course, it may happen that at some subsequent time a piece of this length is required, which would have had to be cut from a long bar if this piece had not been in existence, or, on the other hand, it may have to be put on the scrap heap. Many firms get over the difficulty by the somewhat rough-and-ready process of charging for forgings at a considerably higher rate per cwt. than the iron costs, and the difference is supposed to cover establishment costs and waste. Wages are, of course, charged in addition to this. In this case the iron is charged not to the order number, but to the smithy account, and the smithy is credited with the forging at a higher price per cwt., and at the end of the month with a certain quantity of scrap at a much lower price. Of course, in the other departments the weight of the article is little or no indication of the cost, even to a much less extent than is the case with the foundry and smithy. Some firms even go further in the same direction, and make the price per cwt. cover wages as well. This is convenient, but very unsatisfactory, because there is such a large proportion of guesswork about it, and because, unless the work is all of a similar class, the booked cost bears very little relation to the actual cost. These remarks also apply, with even greater force, to the foundry. In both cases it is well to also credit the smith's shop or the foundry, as the case may be, in a separate column, with the sum for which the casting or forging could have been procured from outside, so that the profit or loss arising from working the smithy or foundry as a separate concern is arrived at. Perhaps the best way to get over this uncertainty is to fix a certain arbitrary length, and charge all over this as returned bar, and all under as scrap. A similar difficulty, of course, occurs in the case of wood for the pattern shop. It is, of course, very desirable to keep an eye on the proportion between the iron used and that turned into forgings, and for this purpose it is advisable, whatever

method is adopted, to open a special account, posted from the iron book, for the purpose in the cost books, so as to prevent the waste bill becoming excessive.

Detail Accounts.—The cost accounts being completed, it is in many cases advisable to sub-divide them, so as to bring out clearly the cost of the various parts of the work to which they refer. This is not necessary or desirable in all cases; but it will often lead to very considerable cheapening of the process of manufacture, and, in cases where parts of the work have to be prepared or renewed, it is necessary to know the costs of such parts, in order to be able to quote prices. The process of preparing these accounts is merely a posting operation, and consists in picking out of the finished accounts the parts that will have to be repeated in order to manufacture the part of the work under consideration.

In the case of steam engines, for instance, it is often very desirable to know the cost of renewing the piston rod and piston of the engine. If, then, it is thought worth while to pick out of all accounts for engines the operations that will be necessary to manufacture these parts, it can easily be done if, and only if, the wages have been entered up in detail, as recommended in the foregoing pages.

If these subsidiary accounts are opened, and a series of such costs have been obtained for different sizes of work, it is extremely useful to plot the prices on squared paper, in the same manner as was recommended for the time curves in an earlier article. The same difficulty as was mentioned in that article will be met in this case, viz., that of finding a self-consistent method of graduating the horizontal axis.

In the case of the steam engine the best principle to adopt, as has been said, is to take the abscissa as the product of stroke and diameter of cylinder. Indeed, in the case of all accounts of similar articles, differing only or mainly in size, this principle of plotting the results will be found to be extremely easy and suggestive, as showing, in a very graphic manner, the character and magnitude of the variations.

In addition to these considerations, there will sometimes be so much work to be done in the shop as to make it extremely advisable to get loose parts of the work done by outside firms. In this case it is of the highest importance for the home firm to know exactly what they will lose by doing this. Indeed, it will sometimes happen that it will be possible to get parts so made outside for less than they can be made at home by firms who make a specialty of that class of business. This fact would never be discovered without such accounts as we have been mentioning. Thus it will sometimes be found that it is possible to procure crank shafts from firms who are principally engaged in making them for actually less money than it would cost to make them at home. It is unnecessary to point out that, whenever this can be done, it is in the highest degree advisable to do it, rather than waste the resources of the shop for the pleasure of doing everything at home. The question will, however, arise as to how far the establishment costs ought to be reckoned as part of the cost of manufacture in a case of this kind. In all probability the total establishment cost would not be increased at all by making them at home, although they are, of course, made to bear their share of it when made in the shop. The drawback is, of course, that when such things are procured from outside it is impossible to know what class of work one will get, and if the firm who make them do not work to the same degree of accuracy that is observed in the home shop, the confusion may be endless.

CHAPTER XI.

Summary and Appendix.

The system explained in the foregoing articles will, it is believed, be found to apply generally to by far the greater number of workshops, large or small, although there may be differences of detail to suit individual classes of work. Throughout the articles we have endeavoured to insist most strongly on the point that the great necessity in a well-managed works is that there should be a definite routine in the issuing of orders, and that the meaning of all orders issued should be absolutely clear. No management is efficient of which this is not a cardinal feature. The function of an efficient manager is primarily to find out exactly what a customer wants, and himself fill in all the blanks which the great majority or customers leave in their orders, and if necessary by further communication with the customer. He must (1) have an absolutely clear conception in his own mind of exactly what is wanted; and (2) be able to transmit his orders in writing, and in an absolutely lucid form to the the workman.

This he does by means of the drawing office to which department he transmits his requirements, not verbally, but by means of the drawing-office instruction book. His entries in this book should be as precise and definite as the nature of the case permits. The workman, be he a draughtsman or mechanic, who knows exactly what he has to do, will do the work in half the time that he will occupy if he has first to find out what is wanted. This principle cannot be too strongly insisted on. It is impossible for anyone to work vigorously on a job if he has only a hazy conception of what he has to do, and loosely-worded or incomplete instructions are responsible for a greater waste of money than anything else, without exception. The draughtsman then embodies these instructions in the drawing and the order sheets. These

should be the sole instructions that the workman needs, and they should be absolutely complete and definite, so that the foreman's and the workman's job should be perfectly straightforward. As we have said, the only persons who should do any designing in the works—that is, whose instructions are not hard and fast—should be the drawing-office staff, and no instructions should be necessary except what are on the drawing. It is positively fatal to efficiency if the manager or anyone else breaks across this system by sending verbal orders into the shop, and it should be an absolutely invariable rule that under no circumstances should any instructions or modification of an order be sent into the shop otherwise than in writing. In works where some of the orders from the customers are given verbally, it will be necessary to have a verbal order book for transmitting these orders to the foreman. Each page of this book is a copy of form A, half foolscap size, and every alternate page is perforated so as to be easily torn out. A carbon paper copy is kept on the counterfoil. This copy may afterwards be transferred to the main order book, and when necessary into the regular order sheets.

The absolute avoidance of verbal orders is necessary, not only in order to avoid mistakes, which will inevitably arise if they are tolerated in any shape or form, but also to ensure that a copy of every order issued is kept for reference. If an order goes into the shop by any of the regular means, it cannot escape being copied, and reference can be made to it afterwards when necessary.

The system of drawing-office control which has been advocated throughout is, the writer firmly believes, the only one which will be found entirely satisfactory. This system has been explained chiefly in connection with repetition work, or shops where the work is largely of one class. In cases where this is not the case, the following modification of the same system will be found to be wholly satisfactory. This system, as here explained, is in use under the author's supervision at the present time.

FORM A.

BROWN & CO., ENGINEERS, TUTBURY.

Order No.....

Date of Order..... *Delivery due.....*

O.N.	PARTICULARS OF ORDER.	DATE COMPLETED.

The order forms are of foolscap size, and printed exactly as given below. The lists are not printed as has been previously explained, but the forms are left blank to be filled in by the draughtsman. In order to produce several copies of these with a minimum of labour, a duplicator is used, and the prepared paper on which the original copy is written is printed and ruled in exactly the same manner as the order sheet, all lines on the one being printed on the other in precisely the same position, so that, when the sheet is properly adjusted in the duplicator, the writing is reproduced in exactly the accurate position on the order sheet. Six copies are taken from each sheet. These copies, of course, contain every separate part of the work as it is required in the completed shape. Absolutely nothing is omitted, down to the very smallest detail. Every screw, nut, and even washer, is specified. A copy is kept for drawing-office use in the following manner: Before the original stencil is destroyed and taken out of the frame, it is carefully laid in the correct position on a page of the "Order-form Book," which is printed and ruled in precisely the same manner as the order sheets are. The inked stencil is then rubbed over with the finger, which leaves a perfect copy in the order-form book, and forms a very convenient record of the job. In the order-form book the name of the customer and similar matters are added in ink, which it would not, of course, be advisable to give in the shop forms.

In some works, where much jobbing work is done, it is advisable to have a special kind of drawing for such work as is not likely to be repeated. These are sketches made in copying ink on sheets of foolscap, which are copied in a press copy book kept in the drawing office, and mounted on cardboard, and marked with the number of the page of the copy book in which the sheet is copied. This is the sketch number of the drawing, and is written thus (Sk. 20/246), showing that that sketch is copied in copy book 20, page 246. The instructions given to the foremen in relation to these sketches should be all written in the order sheet.

FORM B.

BROWN & CO., ENGINEERS, TUTBURY.

PATTERN SHOP INSTRUCTIONS.

Order No..... *Date.....*

These patterns to be finished on.....

No. off.	Description.	D. No.	No. of Pattern.	Old, new, or alteration.	Date completed.	Checked by	Remarks.

FORM C.....*Subject*.....*O.F.B.*.....*Page*.....

BROWN AND CO., Engineers, Tatbury.

LIST OF PARTS *required for O.N.*.....(*continued from O.F.B.*....)

Date of Order..... *To be finished by*.....

No. off.	DESCRIPTION.	D. No.	No. of pattern or sketch.	Shop order No.	Date received, or ordered	Date completed.	Remarks or weights.			
								c.	qr.	lb.

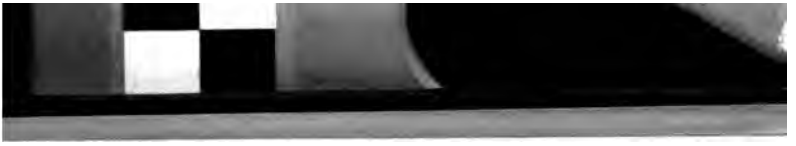
(*Continued on O.F.B.*.....)

Nothing should be left to be communicated verbally where it is possible to write it down, and the meaning of the order should be as absolutely clear as it can possibly be made.

When the lists are completed one copy of each is given to the works manager. The parts that are to be ordered from outside are entered by him into the order to the firm from whom they are to be procured. He also enters the date of ordering on the copy of the order form, and returns it to the draughtsman, who makes the same entry, in red ink, in the "date received" column on each of the other sheets. All the foremen are thereby informed which parts are being made outside. This done, the works manager distributes the forms to the foreman pattern-maker, moulder, smith, fitter, turner, and storekeeper.

When the parts that have been ordered from outside arrive in the works, the storekeeper enters their arrival on the corresponding sheet, in the "completed" column, and also enters the giving out of each of the parts as they are required, along with the weight and any additions that may be required. When all the parts have been given out, the storekeeper sends his sheets up to the costs office, and details are posted to the costs account all at once, thus minimising the labour of cost keeping. Each foreman selects from the sheet his own part of the work, and enters on his copy, in the appropriate column, both the date on which he receives the part or the order and the date on which he finishes it, and returns it to the stores finished as far as his department is concerned. When he has finished with all the parts mentioned in any batch of the sheets, he returns that batch to the drawing office, along with any remarks which may be necessary entered in the appropriate column. These remarks are entered when necessary into the order-form book, and also the date at which each foreman returns his batch of the sheets. These forms, in addition to showing each foreman what he has to do, make it easy to ascertain the exact state of progress of any order.

It is most convenient to take a survey of the work in the



shop by means of a meeting of all the foremen with the works manager, say once a week, or better, once a day, each foreman being provided with all his sheets. By this means all misunderstandings are almost entirely prevented, and if they arise, are most easily cleared up. The works manager has brought before him the exact position of all orders. No thorough co-operation is possible where this meeting is dispensed with.

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